ASSESSMENT OF THE EMERGING BIOCRUISE THREAT

By

Rex R. Kiziah, Lt Col, USAF

The Counterproliferation Papers
Future Warfare Series No. 6
USAF Counterproliferation Center
Air War College

Air University
Maxwell Air Force Base, Alabama

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **Assessment of the Emerging Biocruise Threat**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **USAF Counterproliferation Center,Air University,325 Chennault Circle,Maxwell AFB,AL,36112-6427**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**75**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Assessment of the Emerging Biocruise Threat

Rex R. Kiziah, Lt Col, USAF

August 2000

The Counterproliferation Papers Series was established by the USAF Counterproliferation Center (CPC) to provide information and analysis to assist the understanding of U.S. national security policy-makers and USAF officers to help them better prepare to counter the threat from weapons of mass destruction. Copies of No. 6 and previous papers in this series are available from the USAF Counterproliferation Center, 325 Chennault Circle, Maxwell AFB AL 36112-6427. The fax number is (334) 953-7530; phone (334) 953-7538.

Counterproliferation Paper No. 6
USAF Counterproliferation Center
Air War College

Air University
Maxwell Air Force Base, Alabama 36112-6427

The internet address for the USAF Counterproliferation Center is:
http://www.au.af.mil/au/awc/awcgate/awc-cps.htm

Contents

Disclaimer

The views expressed in this publication are those of the author and do not reflect the official policy or position of the Department of Defense, the U.S. Government, or the USAF Counterproliferation Center.

The Author

Lieutenant Colonel Rex R. Kiziah, USAF (BS, USAF Academy; PhD, The University of Texas at Austin), is currently the Deputy Chief, Theater Air Defense Division in the Air Staff's Directorate of Global Power Programs. Previous assignments include serving as the Air Force Research Laboratory Commander's representative to the National Reconnaissance Office; Deputy Program Manager of the Office of the Secretary of Defense Counterproliferation Support Program; Special Assistant for Research and Technology for the Assistant to the Secretary of Defense for Nuclear, Chemical and Biological Defense Programs; Associate Professor of Physics at the USAF Academy; and Section Chief and Neutral Particle Beam Research Officer at the Air Force Weapons Laboratory. He is a graduate of Squadron Officer School, Air Command and Staff College, Defense Systems Management College and the Air War College.

Acknowledgments

This paper is a product of research conducted during Terms I and III of Academic Year 1999 - 2000 at the Air War College. During these terms, I explored a counter-proliferation topic designated by the USAF Institute for National Security Studies (INSS) as a research area of interest to the counterproliferation community. This particular research area was listed on the INSS's website at http://www.usafa.af.mil/inss/inss.htm as Topic 2.22:

How likely is it that rogue states will be able to employ cruise missiles to deliver Biological Warfare (BW) agents in future conflicts beyond 2005, and what are the implications for the AF and DoD?

- Identify and evaluate developing technologies that could improve the potential use and effectiveness of cruise missiles as BW weapon systems.
- Examine operational and strategic effects of future cruise missile BW attacks.
- Identify those technologies countries may employ using modified cruise missiles to deliver BW agents, as well as which military and civilian targets would be attacked in conflicts past 2005.
- Draw some conclusions regarding the general capabilities and effects of using cruise missiles to deliver BW payloads in future conflicts.

In order to bound my efforts, I did not attempt to fully explore this INSS topic. Instead, I focused my research on exploring the reasons rogue nations would attempt to acquire land-attack cruise missiles (LACMs), how these cruise missiles could be acquired, what were the missile attributes that made them effective BW agent delivery platforms, and how might LACM/BW weapon systems be used against the U.S. and its allies?

I would like to acknowledge the help of Scott McMahon, an expert in the proliferation of LACMs and their enabling technologies. Scott graciously provided a significant amount of his time to discuss with me the details of how rogue states might acquire or develop LACMs, answered my numerous emails, and provided me with some unpublished presentations that were valuable in increasing my understanding of the proliferation issues and in writing this paper.

Illustrations

Tables

Abstract

The rogue nations—Iran, Iraq, Libya, North Korea, and Syria—are pursuing the acquisition of land-attack cruise missiles as part of a mix of aircraft, ballistic- and cruise-missile long-range strike forces. A major reason for these acquisitions is that a land-attack cruise missile configured to disseminate biological warfare agents comprises a technically and economically attractive, yet highly lethal weapon of mass destruction. Such a weapon system serves as a lever of strategic power available to rogue nations who want to deter, constrain or harm the U.S. and its allies, but of necessity, must challenge the conventionally superior Western forces via asymmetric means. Aiding the rogue nations' pursuit of these biological weapon systems are the dual-use nature and availability of the materials, technologies, and equipment for producing biological warfare agents and the widespread proliferation of the enabling technologies for land-attack cruise missiles, such as satellite navigation and guidance; compact, highly-efficient engines; and composite, low-observable airframe materials. With these technologies and some limited foreign assistance from countries such as China and Russia, many of the rogue nations can indigenously produce land-attack cruise missiles. Also, they will increasingly be able to directly purchase these missiles. The number of countries other than the U.S. that will be producing advanced, long-range, land-attack cruise missiles will increase from two to nine within the next decade, and some producers are expected to make them available for export. Or, they can choose to convert antiship cruise missiles, which have been widely proliferated and are in the rogue states' military arsenals, into land-attack missiles. With the abundant proliferation pathways for biological warfare agents and land-attack cruise missiles, it is quite probable that by the 2005 timeframe one or more of the rogue nations will possess a long-range, land-attack cruise missile for use as a biological weapon system (biocruise) against the U.S. and its allies and their worldwide military operations.

Assessment of the Emerging Biocruise Threat

Rex R. Kiziah

I. Background: Emergence of the Land-Attack Cruise Missile as a Weapon of Choice

> *The simultaneous proliferation of cruise missile delivery systems and BTW [biological and toxin warfare] production capabilities may pose a serious strategic threat in the future.*
>
> --Jonathan B. Tucker[1]

The utility of having cruise missiles in a nation's military arsenal was clearly demonstrated to the world during January 16 - February 2, 1991 when U.S. Navy surface ships and submarines in the Persian Gulf, Red Sea and Eastern Mediterranean launched 288 Tomahawk Land-Attack Missiles (TLAMs) and the U.S. Air Force expended 39 Conventional Air-Launched Land-Attack Cruise Missiles (CALCMs) against "strategic" targets in Iraq. These targets included command and control headquarters, power generation complexes, weapons of mass destruction (WMD) facilities, and oil production and refining factories.[2] Although there is some disagreement between official Department of Defense (DoD) sources and outside analyses on the success of these land-attack cruise missile (LACM) strikes, the overall consensus, both official and non-official, is that the LACMs proved to be very effective weapon systems. As stated in the DoD's *Conduct of the Persian Gulf Conflict: Final Report to Congress*, "The cruise missile concept--incorporating an unmanned, low-observable platform able to strike accurately at long distances--was validated as a significant new instrument for future conflicts."[3] Just how significant a new instrument the cruise missile would become did not take long to unfold.

Since the 1991 Persian Gulf War, the LACM has become a U.S. weapon of choice in punishing belligerents' transgressions, coercing national leaders to behave according to U.S. wishes and deterring adversaries' plans against U.S. interests. The following examples, which

are not all inclusive, illustrate the extensive U.S. employment of LACMs since 1991.[4] In 1993, to successfully coerce Iraqi President Saddam Hussein to allow United Nations (UN) Special Commissioners inside Iraq to conduct UN-approved WMD inspections, the U.S. used TLAMs to destroy a suspected nuclear fabrication facility near Baghdad. Five months later, in June 1993, two dozen TLAMs were launched against Iraqi intelligence headquarters in retaliation for an Iraqi assassination attempt against former President Bush. In September 1995, the U.S. Navy used 13 TLAMs to strike Bosnian Serb air defense targets in northwestern Bosnia after the Serbs shelled the Tuzla airport, a UN-designated “safe area.” Once again punishing Iraqi leadership and forcing the Hussein Regime to behave as the U.S. desired, the U.S. used approximately 50 TLAMs over a two-day period in September 1996 to attack Iraqi command and control networks, Hawk missile batteries, and other selected targets in response to Saddam's assault on Kurdish rebels and the seizure of the northern city Irbil. Promptly retaliating for the deadly bombings of U.S. embassies in Kenya and Tanzania in August 1998, the U.S. Navy launched 79 TLAMs against Osama bin Laden's three-facility “terrorist university” complex in Afghanistan and the El Shifa Pharmaceutical Factory and Chemical Complex in Khartoum, Sudan, at which bin Laden was suspected of trying to develop WMD. Once again, in an effort to coerce Saddam, in December 1998, the U.S. began Operation Desert Fox by launching some 200 TLAMs against targets such as a missile design and production facility in Al Taji; Iraq's Special Security Services headquarters; and one of Saddam's presidential palace sites, Jabul Makhul, suspected of containing command offices, bunkers and elements of Iraq's WMD programs. Secretary of Defense William Cohen stated: “It would be my hope that following this operation, Saddam Hussein would see the wisdom of finally complying with UN weapons inspections.”[5] Most recently, the U.S. extensively employed cruise missiles (both TLAMs and CALCMs) during the March - June 1999 Operation Allied Force 78-day air campaign against Serbian President Slobodan Milosevic and his army. In fact, the rate of cruise missile use was so high, that defense planners became very concerned about depleting the inventory.

As the above events illustrate, LACMs have become a centerpiece of the U.S. military instrument of power and their use has expanded

dramatically since the Gulf War. The U.S. prizes its LACMs for their ability to penetrate enemy air defenses, strike at long ranges (over 1,000 miles from the launch platform for the TLAM), and most importantly, do so without endangering the lives of U.S. armed services personnel. The U.S. LACMs are the ultimate "smart weapons." Not only the U.S., but the rest of the world has observed and learned. Given the U.S.'s prominent, overall successful and escalating use of these weapon systems throughout the 1990s, along with the proliferation of enabling technologies such as precision navigation and guidance, compact and efficient turbojet and turbofan engines, and composite and low-observable materials, it should be no surprise that countries around the world, including the U.S.-labeled rogue nations, desire and are actively pursuing cruise missiles, especially land-attack versions.[6]

Rogue nations value LACMs not only for their long-range, precision strike capabilities using conventional, high-explosive warheads but also for their potential use in delivering chemical and biological warfare agent payloads. Advances in dual-use technologies such as satellite navigation (U.S. Global Positioning System (GPS) and Russian Global Navigation Satellite System (GLONASS)) and highly-efficient, small turbofan engines used in aircraft, while allowing the Western nations to improve their long-range, precision strike weaponry, are also enabling lesser developed countries to close the technology gap and begin inserting comparable weaponry into their arsenals relatively "on the cheap" by historical standards and compared to other weapons systems such as modern aircraft and ballistic missiles. Additionally, with many years of determined efforts that have recently intensified, the U.S. has pursued theater missile and air defense systems to counter developing and rogue countries' aircraft and increasingly sophisticated ballistic missiles, in particular. Consequently, potential adversaries are acquiring and developing hard-to-detect and engage LACMs to maintain, and possibly enhance, their capabilities to deter and confront the U.S. and its allies.

These developments have clearly caught the attention of government officials, defense planners and intelligence analysts. Dr. Ramesh Thakur, Vice Rector of the United Nations University, Tokyo, and author of numerous proliferation and arms control articles, stated at a March 1999 arms control conference sponsored by the U.S. Air Force Institute for National Security Studies: "For developing and rogue countries, the balance in cost, accessibility, lethality, complexity, and operational

requirements is shifting from ballistic to cruise missiles."[7] More specifically, Donald Rumsfeld, former Secretary of Defense and chairman of the Congressionally-mandated 1998 Commission to Assess the Ballistic Missile Threat to the United States, stated in an April 1999 address to the National Defense University Foundation: "The United States must expect such states as Iran, Iraq, and North Korea to acquire or develop cruise missiles over the next few years."[8] Echoing this assessment, the National Intelligence Council's September 1999 unclassified report, *Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015*, contains the following: "We expect to see acquisition of LACMs by many countries to meet regional military requirements."[9] Thus, the emerging trend seems to indicate that, in the long term, the greater threat to stability in the various regions around the world of interest to the U.S. may be cruise missiles instead of ballistic missiles.

This paper focuses on a subset of the growing threat of cruise missiles by examining rogue nation acquisition and use of LACMs to deliver biological warfare (BW) agents against future U.S. military operations in regional conflicts around the world and also against military and civilian targets within the U.S. and allied countries. Chapter II discusses some of the motivations and incentives for a rogue state to acquire WMD and their means of delivery, particularly biological weapons, along with highlights of the current assessments (based only on unclassified sources) of the five U.S.-identified rogue states' BW capabilities. Chapter III describes the characteristics and key enabling technologies of LACMs and those attributes that make the LACM desirable as a delivery platform for BW agent payloads. Chapter IV examines the multiple acquisition and proliferation pathways that rogue and lesser developed countries are likely to exploit to obtain LACMs. Also, there is a somewhat detailed discussion of a specific, very plausible indigenous development method that rogue nations could use to develop and deploy a LACM/BW weapon system within a relatively short time period of 4 to 10 years, depending upon the extent of foreign assistance. Lastly, Chapter V concludes the paper with a summary of some of the opinions and estimates of the U.S. intelligence community and an overall assessment to answer the question posed by the U.S. Air Force Institute for National Security Studies: "How likely is it

that rogue states will be able to employ cruise missiles to deliver BW agents in future conflicts beyond 2005?"

II. Reasons Rogue Nations Acquire Biological Weapons and Assessment of their BW Programs

> *The points to keep in mind about the new world of mass destruction are the following. . . . [T]he roles such weapons play in international conflict are changing. . . . Increasingly, they will be weapons of the weak--states or groups that militarily are at best second-class. The importance of the different types among them has also shifted. Biological weapons should now be the most serious concern, with nuclear weapons second and chemicals a distant third.*
>
> --Richard K. Betts[10]

Motivations and Incentives to Acquire WMD

Military and Economic Levers of Strategic Power

There are numerous reasons for rogue countries to pursue WMD and their means of delivery. The most compelling motivation may be that WMD are the only viable levers of strategic power in the post-Cold War world for these nations. They are the rogue Regimes' most realistic means to do the three things they desire to do but cannot accomplish with the conventional military forces they are capable of fielding--deter, constrain and harm the U.S. During the 1991 Persian Gulf War, the U.S. demonstrated to the world that it had developed overwhelming superiority in conventional military force against any other nation. Although since the Gulf War, the U.S. defense budget has decreased significantly, so have the budgets of most other countries, and no country appears to be narrowing the U.S. superiority gap. Currently, the defense budget of the U.S. is more than triple the budget of any potentially hostile nation and more than the combined military spending of Russia, China, Iran, Iraq, North Korea, and Cuba.[11] And as Richard Betts, the Director of National Security Studies at the Council on Foreign Relations, further notes, ". . . there is no evidence that those countries' level of military professionalism is rising at a rate that

would make them competitive even if they were to spend far more on their forces."[12] Rogue nations and other potentially hostile states simply cannot currently, and in the foreseeable future, successfully confront the U.S. on conventional military terms.

Betts, concisely describes the lesser developed countries' conventional military situation vis-à-vis the U.S.:

> Rolling along in what some see as a revolution in military affairs, American forces continue to make unmatched use of state-of-the-art weapons, surveillance and information systems, and the organizational and doctrinal flexibility for managing the integration of these complex innovations into "systems of systems" that is the key to modern military effectiveness. More than ever in military history, brains are brawn. Even if hostile countries somehow catch up in an arms race, their military organizations and cultures are unlikely to catch up in the competence race for management, technology assimilation, and combat command skills.[13]

That many countries are fully aware of this situation and see WMD and their delivery vehicles as an effective means of asymmetrically challenging the U.S.'s overwhelming conventional military power is clearly illustrated by the remarks of the Indian Defense Minister and a former Indian Army Chief of Staff in summarizing their country's main lessons from the Persian Gulf War: "Don't fight the United States unless you have nuclear weapons," and "the next conflict with the United States would involve weapons of mass destruction."[14] In essence, WMD can be a weaker country's equalizer to the larger and more advanced conventional forces of the U.S. and its allies.

WMD, combined with stand-off delivery systems, provide lesser developed countries far less expensive, yet qualitatively superior military and political options for deterring, constraining and harming the U.S. as compared to pursuing advanced conventional forces, whose price tag is prohibitive. In other words, WMD and long-range delivery systems allow countries to achieve their regional and strategic objectives "on the cheap." Rogue nations see WMD as an inexpensive means of coercing neighbors,

deterring outside intervention, deterring other WMD threats and aggression against their interests, and directly attacking the U.S. and its allies, if necessary.

Although not a rogue nation, China's actions and rhetoric clearly illustrate the importance of WMD to developing countries. A senior Chinese military officer reportedly stated that the U.S. would not become substantively involved in a Chinese military move against Taiwanese independence because U.S. leaders “care more about Los Angeles than they do about Taiwan.”[15] And obviously believing in the efficacy of their long-range nuclear missile capability in deterring U.S. involvement in what they consider internal matters, during 1996, China launched multiple short-range ballistic missiles in international waters near Taiwan to successively squelch independence movements during Taiwan's first democratic presidential election.

That countries would currently pursue WMD as a less costly and perhaps the only realistic military means of achieving national objectives is similar to the decisions in the 1950s and 1960s of the declared nuclear powers--U.S., Russia, United Kingdom, France, and China--to pursue strategic power “on the cheap” by acquiring nuclear weapons and strategic delivery systems. As an example, the U.S. expenditure on strategic nuclear systems (nuclear warheads, strategic bombers, missiles and submarines) during the Cold War was, on average, only 10 to 15 percent of the U.S. defense budget.[16]

Technology and WMD Proliferation

The widespread proliferation of enabling technologies and the weapon systems themselves, along with ineffective post-Cold War barriers to their proliferation, are allowing rogue nations to fulfill their desires to cost-effectively acquire WMD and associated delivery systems. In the nuclear arena, India and Pakistan are prime examples of how determined states will pursue and acquire WMD regardless of the international treaties, agreements, and sanctions erected to prevent their acquisition and the subsequent stigmatization of the proliferator by the international community. In all areas of WMD--nuclear, biological, and chemical (NBC) weapons and delivery systems such as ballistic missiles, aircraft, and unmanned aerial vehicles (UAVs)--Iraq surprised the international

community with the expansiveness of its WMD programs. These programs continued in spite of pre-Gulf War proliferation barriers, the concentrated attacks during the Gulf War, comprehensive international sanctions, and the unprecedented intrusiveness of the UN Special Commission (UNSCOM) on Iraq, all directed at destroying Iraq's WMD capabilities. Further exacerbating the proliferation problem is the abundance of countries willing to provide foreign assistance, offering WMD and delivery systems for direct purchase, and providing components and technologies for in-country production. The most notorious are China, North Korea, and Russia who are actively involved (and have been for many years) in assisting the U.S.-labeled rogue nations to develop WMD arsenals.

Difficulties Deterring WMD Use

Another trend enhancing rogue states' desires to acquire WMD and various delivery systems is the erosion of inhibitions on WMD use. Iraq, in particular, has clearly demonstrated the willingness to use WMD on the battlefield. Throughout the 1980 - 1988 Iraq-Iran War, Iraq employed chemical warfare (CW) agents against Iranian troops. In 1983, Iraq fired at least 33 Scud missiles at Iranian targets and is believed to have employed mustard gas on some of the missile launches against Iranian forces. During the last year of the war, in March - April 1988, Iraq attacked Tehran with 200 Scud missiles, causing approximately one-quarter to one-half of the city's residents to flee fearing that some of the Scuds were armed with poison gas warheads.[17] That these Iraqi WMD attacks and others had a deep and lasting impression on Iranian leaders and their views of the effectiveness and international acceptability of WMD is vividly illustrated with the following 1988 remarks of then President Rafsanjani to some Iranian soldiers:

> With regard to chemical, bacteriological, and radiological weapons training, it was made very clear during the war that these weapons are very decisive. It was also made clear that the moral teachings of the world are not very effective when war reaches a serious stage and the world does not respect its own resolutions and closes its eyes to the violations and all the aggressions which are committed

> on the battlefield. We should fully equip ourselves both in the offensive and defensive use of chemical, bacteriological, and radiological weapons. From now on you should make use of the opportunity and perform this task.[18]

Also, during the Iraq-Iran War, Iraq became the first country to use nerve agents against an adversary on the battlefield and on its own population as well. And during the 1991 Persian Gulf War, Iraq deployed modified Scuds armed with CW and BW payloads along with other large quantities of CW agents for use by Iraqi troops. Some 25 Scuds were armed with BW agents, including 10 with anthrax.[19] Saddam also had a dedicated aircraft in a hardened shelter equipped with spray tanks for dispersing BW agents. Had he employed this weapon on the first day of the ground war, the Office of the Secretary of Defense has assessed that over 76,000 of the 320,000 coalition troops southeast of Kuwait City would have died if they had not been vaccinated against anthrax. Apparently, Hussein was deterred from using his WMD by U.S. and Israeli threats of nuclear retaliation.

The credibility of the U.S.'s historically successful, punitive deterrence of WMD by threatening nuclear retaliation may be declining. Richard Betts poses and opines a brief answer to a very relevant and interesting question: "Would the United States follow through and use nuclear weapons against a country or group that had killed several thousand Americans with deadly chemicals? It is hard to imagine breaking the post-Nagasaki taboo in that situation."[20] What if Hussein had used BW agents to kill 76,000 troops at the beginning of the Gulf War? Further addressing the credibility of the U.S.'s nuclear deterrent, Dennis Gormley and Scott McMahon, experts in the area of proliferation of WMD and delivery systems, note:

> This seems to have convinced Saddam Hussein not to use his chemical or biological weapons in 1991. But there are reasons to believe that future threats of nuclear retaliation will neither deter NBC strikes nor reassure regional allies enough that they would permit Western use of their bases while under the threat of NBC attack. Senior U.S. military

> officers, for example, have declared that they would not condone nuclear retaliation under any circumstances, even if NBC weapons were used against the United States. Although such comments are unofficial, when they are combined with a termination of nuclear testing and the virtual elimination of nuclear planning, it becomes apparent that nuclear deterrence is fast becoming an existential rather than practical option.[21]

Another issue with exercising deterrence to prevent WMD use is that deterrence relies on retaliation, and retaliation requires knowledge of who has launched the attack. Combining a WMD such as a BW agent, which inherently creates difficulties in identifying the source of the resulting disease, with a delivery system such as a long-range LACM, which can be programmed to fly circuitous routes to the target, may provide a rogue state with a nonattributable method of attack, thus eliminating any attempts at retaliation.

National Prestige

A final factor to be discussed as influencing a country's decision to acquire WMD and their delivery systems is national prestige. Robert Gates, a former Director of Central Intelligence, stated the following about WMD: “These weapons represent symbols of technical sophistication and military prowess--and acquiring powerful weapons has become the hallmark of acceptance as a world power.”[22] Similarly, referring specifically to the WMD means of delivery, “some Regimes in the developing world see a missile force as a talisman which imparts international respect and ushers them into the company of the great powers.”[23] For this symbolic effect, the rogue countries and others such as China, India, and Pakistan have primarily focused on acquiring ballistic missiles; however, the performance of the U.S. TLAMs during the Gulf War has perhaps elevated the prestige of LACMs to that of ballistic missiles. As Richard Speier, a consultant for the Carnegie Non-Proliferation Project, has noted: “In the Gulf War the U.S. used three times as many cruise missiles as the Iraqis used ballistic missiles, and our cruise missiles had a very telling military effect.”[24] This lesson has

probably been well absorbed by potential adversarial countries around the world.

Advantages to Acquiring Biological Weapons

Can Cause Large Numbers of Casualties

Having provided some of the motivations for rogue states and lesser developed countries to acquire WMD and their delivery systems, the following paragraphs highlight some of the reasons why Betts and many others view biological weapons as the most serious proliferation concern. (Table 1 captures the salient points of the following paragraphs in a very abbreviated form.) One of the main reasons can be summed up simply with a slight modification to a popular phrase--biological weapons provide "more bang for the buck and effort." As Betts observes, biological weapons combine maximum lethality with ease of availability. Nuclear weapons wreak massive destruction but are extremely difficult and costly to acquire, chemical weapons are fairly easy to acquire but possess limited killing capacity, and biological weapons possess the "best" qualities of both.[25] (Note: Biological weapons most closely resemble a special category of nuclear weapons called "neutron bombs." They harm people, not property, with lethal effects against living organisms.)

Table 1. Comparison of NBC Weapons

				Effectiveness			
				Protected Personnel		Unprotected Personnel	
Type	Technology	Cost	Signature	Tactical	Strategic	Tactical	Strategic
Biological	+	-	-	-	-	+	++
Chemical	+	+	+	-	-	++	+
Nuclear	++	++	++	++	++	++	++

++: Very High +: High -: Lower

Source: Lester C. Caudle, "The Biological Warfare Threat," in *Medical Aspects of Chemical and Biological Warfare*, eds. Frederick R. Sidell, Ernest T. Takafuj, and David R. Franz (Washington, D.C.: Office of The Surgeon General at TMM Publications, 1997), 459.

Table 2 contains examples of pathogens (bacteria and viruses) and toxins that are generally considered to be good BW agents for effective employment as biological weapons. Edward Eitzen, a medical doctor with the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID), noted that it has been estimated that cruise missile delivery of anthrax under suitable weather conditions could cover an area of comparable size to that of the lethal fallout from a ground-burst nuclear weapon.[26] More rigorously, the Congressional Office of Technology Assessment conducted a study in 1993 investigating the airplane dissemination (assumed to be dispensed in an effective manner) of 100 kilograms of anthrax as an aerosol cloud over Washington, D.C. on a clear and calm night (good environmental conditions). The study showed that between one and three million people could be killed--300 times the number of fatalities that could be caused by a similar release of 10 times the amount of sarin gas.[27] An earlier 1970 study by the World Health Organization had shown that an attack on a large city (five million people) in an economically developed country such as the U.S. using 50 kilograms of anthrax disseminated from a single airplane under favorable conditions could travel downwind in excess of 20 kilometers, thus affecting a large area and killing upwards of 100,000 people and incapacitating another 250,000.[28] Additionally, U.S. military scientists verified the order of magnitude effects of BW agent release against urban populations estimated by these studies by conducting combat effects investigations at Dugway Proving Ground, Utah.[29] Thus, when comparing the killing power of WMD, on a weight-for-weight basis, BW agents are inherently more toxic than CW nerve agents, and biological weapon systems can potentially provide broader coverage per pound of payload than CW weapons.[30]

Table 2. Candidate BW Agents for Weaponization

Disease	Causative Agent	Incubation Time (Days)	Fatalities (Percent)
Anthrax	*Bacillus anthracis*	1 to 5	80
Plague	*Yersinia pestis*	1 to 5	90
Tularemia	*Francisella tularensis*	10 to 14	5 to 20
Cholera	*Vibrio cholerae*	2 to 5	25 to 50
Venezuelan equine encephalitis	*VEE virus*	2 to 5	< 1
Q fever	*Coxiella burnetti*	12 to 21	< 1
Botulism	*Clostridium botulinum toxin*	3	30
Staphylococcal enterotoxemia	*Staphylococcus enterotoxin type B*	1 to 6	< 1
Multiple organ toxicity	*Trichothecene mycotoxin*	Dose Dependent	

Source: *The Biological & Chemical Warfare Threat* (Washington, D.C.: U.S. Government Printing Office, 1999), 2.

Economically and Technically Attractive

In addition to being extremely lethal and offering nations a feasible alternative to nuclear weapons as a strategic arsenal, biological weapons are economically and technically attractive, or as Betts described, easily available compared to nuclear and chemical weapons. The costs of a BW program are much lower than for nuclear and chemical weapons programs: estimates are $2 to $10 billion for a nuclear weapons program, tens of millions for a chemical program and less than $10 million for a BW program.[31] Adding to the appeal of biological weapons, almost all the materials, technology, and equipment required for a modest BW agent program are dual-use, obtainable off the shelf from a variety of legitimate enterprises and widely available. And the technical skills required to

initiate and conduct an offensive BW agent production program are commensurate with those of graduate-level microbiologists, thousands of whom are available worldwide and many of them trained in the best Western universities.[32]

The most significant technical hurdle to overcome in obtaining biological weapons is weaponization of the BW agents. The primary weaponization concerns are (1) effective dissemination of the BW agent for maximum effect (area coverage and lethality or incapacitation); (2) maintaining the viability and virulence of the BW agent; and (3) selecting the appropriate delivery system and conditions.[33] BW agents should be disseminated as an aerosol cloud for maximum infectivity via inhalation through the lungs and for maximum areal coverage. Obtaining the right aerosol particle size is extremely important. Seth Carus, a world-renowned expert and prolific writer on proliferation issues, notes that aerosolized BW agents of the wrong size could render a BW attack completely ineffective.[34] The ideal particle size ranges from one to five microns in diameter. An aerosol formed from particles in this size range is stable and can be carried downwind over long distances without significant fallout of the BW agent particles. Also, one to five microns is the ideal particle size range for retention in the lungs--particles less than one micron are readily exhaled, and particles greater than five microns are filtered out by the upper respiratory passages and do not make it to the lowest level of the lungs.

BW agents can be produced and aerosolized in either liquid or dry powder form. The liquid form is easier to produce but has a relatively short shelf life (most liquid BW agents can only be stored for three to six months under refrigeration) and can be difficult to aerosolize. Commercial sprayers can be modified for disseminating liquid BW agents, but there are nontrivial issues associated with the clogging of the sprayer nozzles and destroying the agent during the spraying process.[35] Both the shelf life and spraying limitations can be overcome by producing BW agents in dry form through lyophilization (rapid freezing and subsequent dehydration under high vacuum) and milling into a powder of the appropriate particle sizes. Anthrax spores produced in this fashion can be stored for several years.[36] However, producing dry BW agents is

extremely hazardous and requires more specialized equipment and greater technical capabilities.

Whether in liquid or dry form, weaponization of BW agents must address and overcome the environmental conditions, which kill or reduce the virulence of the agents. The rate of biological decay depends on numerous factors such as ultraviolet radiation, temperature, humidity, and air pollution.[37] The optimal atmospheric conditions for a BW attack would occur on a cold, clear night with the relative humidity greater than 70 percent. The inversion layer (blanket of cool air above the cool ground) would prevent vertical mixing of the aerosol cloud, thus keeping the BW agent near the ground for inhalation.

As clearly indicated above, weaponization of BW agents presents many challenges. Nonetheless, from a proliferation viewpoint, it is important to note that more than 40 years ago the U.S. Army Chemical Corps overcame these challenges and successfully demonstrated and conducted tests of large area and effective dissemination of biological agents.[38]

Clandestine Acquisition

Because of the low costs associated with initiating and conducting a biological weapons program and the dual-use nature of BW research and equipment, a BW program can be carried out clandestinely, disguising the BW activities as legitimate research or completely concealing them. This is a unique feature of biological weapons programs compared to chemical and nuclear weapons programs that may make them particularly attractive to rogue nations. There are no unambiguous signatures that easily discriminate a program which is conducting legitimate biomedical research on highly contagious diseases vis-a-vis a program researching and producing BW agents for offensive military purposes. Adding to the difficulty of uncovering a clandestine BW program is the absence of verification provisions in the Biological and Toxin Weapons Convention. As the Iraqi situation has clearly illustrated to the international community, detecting and understanding the extent of a clandestine BW program are extremely difficult. In January 1999, UNSCOM Iraq provided a report to the UN Security Council summarizing eight years of extensive investigations and destruction of Iraq's chemical and biological weapons programs. Even with these intensive and powerful (anytime, anywhere) inspections, UNSCOM officials now believe that Iraq, through

well-coordinated concealment and deception efforts, may have produced another, as yet unidentified, BW agent in an unreported and unlocated production facility.[39]

Clandestine Use

From an aggressor's perspective, another advantage of biological weapons over chemical or nuclear weapons is that there are currently no highly reliable detection devices available to provide advanced warning of a BW attack, thus allowing a greater probability of large numbers of casualties per weapon use. Additionally, coupled with the delayed onset of symptoms from a BW attack and the fact that these symptoms could easily be attributed to a natural outbreak of disease, biological weapons potentially provide the country employing them plausible deniability. Thus, an attacker may use biological weapons as a precursor to a conventional military attack to wreak havoc and weaken the target forces of a conventionally superior foe with a reduced risk of retaliation and condemnation from the attacked country and international community. (Note: It would likely be possible to identify a large outbreak of something such as anthrax as an almost certain BW attack since large outbreaks of this disease occur rarely, if at all, in nature. However, the outbreak of a common disease regularly found in a given region of the world would possibly be seen at first as a natural outbreak.)

Assessment of Rogue State BW Capabilities

As the previous paragraphs have shown, for those nations desiring to acquire WMD, biological weapons offer some technical, economic, military, and political advantages over both chemical and nuclear weapons. Thus, it is understandable (but highly undesirable from a U.S. perspective) that many countries currently possess, are probably actively pursuing or could potentially develop biological weapons. According to an assessment by the Center for Nonproliferation Studies (CNS) at the Monterey Institute of International Studies, 11 countries have BW programs that range from possible BW agent research activities to production and maintenance of an offensive biological weapons capability.[40] Table 3 summarizes the CNS assessment. All five of the

U.S.-labeled rogue states--Iran, Iraq, Libya, North Korea, and Syria--are believed to have offensive BW programs.

Table 3. International Biological Warfare Agent and Weapons Programs

Country	Program Status	Possible Agents
Algeria	Researching biological weapons, but no evidence of production	Unknown
China	Probably maintains an offensive BW program	Unknown
Egypt	Researching biological weapons	anthrax, botulinum toxin, plague, cholera, tularemia, glanders, brucellosis, melioidosis, psittacosis, Q fever, Japanese B encephalitis, Eastern equine encephalitis, influenza, smallpox, mycotoxins
Iran	Researching biological weapons; probably has produced BW agents and weaponized a small quantity	Unknown
Iraq	Previously active research and production program; probably retains elements of its BW program	anthrax, botulinum toxin, gas gangrene, aflatoxin, trichothecene mycotoxins, wheat cover smut, ricin, hemorrhagic conjunctivitis virus, rotavirus, camel pox
Israel	Researching biological weapons, but no evidence of production	Unknown
Libya	Researching biological weapons	Unknown
North Korea	Has researched biological weapons since early 1960s	anthrax, cholera, plague, smallpox, botulinum toxin, hemorrhagic fever, typhoid, yellow fever
Russia	Possible research and production programs beyond legitimate defense activities	Extensive list from “A to Z”
Syria	Researching biological weapons; program may have reached weaponization stage	anthrax, cholera, botulinum toxin
Taiwan	Possible research program	Unknown

Source: Center for Nonproliferation Studies, Monterey Institute of International Studies, "Chemical and Biological Weapons Possession and Programs: Past and Present," n.p.; on-line, Internet, 14 February 2000, available from http://www.cns.miis.edu/research/cbw/possess.htm.

Iran

Arnold Beichman, a reporter for *The Washington Times*, concludes that Iran's BW efforts are part of its overall campaign to become the dominant power in the Middle East, and in his view, Iran is a greater danger to the world than Iraq.[41] According to Paula DeSutter, a former Senior Fellow for Arms Control and Nonproliferation at the former Arms Control and Disarmament Agency (ACDA), in its quest to become the regional hegemon, "Iran considers the United States to be the primary threat to Iranian interests, and U.S. forces in the region could well be perceived by Iran as lucrative targets for NBC weapons--which Iran will be able to deliver through both traditional and novel means, presenting challenges to U.S. defenses."[42] Furthermore, DeSutter emphasizes that Iran's use of NBC will be particularly difficult to deter and that, in fact, the possibility of the U.S. failing to deter future Iranian use of WMD is significant.

Some of the reasons for DeSutter's dire assessment were alluded to in the introduction of this paper. Having been the victims of extensive WMD use, the Iranians emerged from the 1980 - 1988 Iran-Iraq War determined to develop WMD and missile delivery systems to deter future Iraqi aggression. This desire to develop a WMD deterrent capability was further strengthened by a key lesson learned from the 1991 Gulf War. As was the case for Iraq's military, Iran's conventional forces would not be able to prevent U.S. actions in the region. Thus, Iranian leaders view WMD and their means of delivery as an essential component of the military capabilities required to ensure Iran's security.

Beichman reported that Iranian President Mohammed Khatami has created a science and technology group of advisers, headquartered in the Mahsa Building in Tehran, to supervise his Regime's NBC programs. These programs include four different groups currently engaged in producing biological weapons: Special Industries Organization of Iran's Ministry of Defense, Research Center of the Construction Crusade, Revolutionary Guard Corps research at Imam Hossein University, and The

Biotechnology Research Center. Additionally, the Iranians have hired Russian, Chinese, and North Korean BW experts to work at these facilities.[43] Based on official unclassified DoD, Central Intelligence Agency (CIA) and ACDA reports, Iran has investigated since the early 1980s both pathogens and toxins as BW agents, produced some agents, and apparently weaponized a small quantity of those produced. Iran is judged to be able to support an independent BW program, possesses the in-house capacity for large-scale agent production, and could have an indigenously developed BW warhead for ballistic missile delivery around the 2000 timeframe. Iran is also expected to employ cruise missiles with spray tanks as future BW agent delivery systems.[44]

Iraq

The almost continuous and surprising revelations about Iraq's BW programs, and the phenomenal concealment and deception efforts undertaken to deny information to the UNSCOM from the beginning of its inspections of Iraq's BW activities, clearly show the importance of biological weapons to rogue countries. Richard Butler, the former executive chairman of the UNSCOM, recently commented that of the panoply of Iraq's NBC programs, the BW programs have been the most important to Saddam. Butler remarked:

> Over nine years now, Iraq has consistently made extraordinarily strenuous efforts to hide the biological program--well beyond those they made on missiles or chemicals. Why? Why? No effort was too much to prevent us from getting to the truth. That says to me it was big and nasty.[45]

During these nine years, UNSCOM inspectors, along with the 1995 defection of Iraqi General Hussein Kamal Hassan, have revealed that Iraq's BW was far more extensive and advanced before the 1991 Persian Gulf War than anyone had suspected.

Iraq produced three bacterial agents (*Bacillus anthracis*, *Clostridium botulinum* and *Clostridium perfringens*), the fungal toxin aflatoxin, the plant-derived toxin ricin, and the fungal antiplant agent wheat smut and conducted research on other fungal toxins such as *tricothecene*

mycotoxins. Iraq also carried out a research program on three viral agents--infectious hemorrhagic conjunctivitis virus, rotavirus, and camel pox.[46] Some of these BW agents were weaponized before the Gulf War: 166 bombs (100 botulinum toxin, 50 anthrax, 16 aflatoxin); 25 Scud/A1 Hussein missile warheads (13 botulinum toxin, 10 anthrax, 2 aflatoxin); 122-mm rockets filled with these three agents; spray tanks capable of being fitted to a fighter or remotely piloted aircraft and spraying 2,000 liters of BW agents over a target area; and artillery shells filled with BW agents.[47] As discussed in the 1999 UNSCOM report to the UN Security Council, former UNSCOM officials now believe that Iraq may have produced another BW agent (that has yet to be disclosed) in an unreported and unidentified production facility that is possibly underground. Milton Leitenberg, a biological weapons expert at University of Maryland's Center for International and Security Studies, noted that there are suggestions that this agent is *Yersinia pestis*, *Brucella mellitensis* or a viral agent. If the agent is viral, then Iraq's BW program is even more sophisticated that the current information reveals.[48] Leitenberg also highlighted that Iraq has developed an indigenous capability to produce BW growth media and has constantly worked to achieve domestic manufacturing capabilities for BW production and processing equipment in order to eliminate dependence on outside sources and assistance for its BW program.

The bottom line is that even after the targeted destruction of Iraq's BW capabilities during the Gulf War and the subsequent nine years of UNSCOM discovery and elimination activities, the Hussein Regime still possesses a BW capability. Their resources probably include some stockpiled BW agents such as anthrax, agent seed stocks, growth media, sprayers for Mirage F-1 aircraft, BW munitions, and the technical expertise and equipment to quickly resume production of anthrax, botulinum toxin, Clostridium perfringens, and aflatoxin, including the ability to produce BW agents in dry form and milled for optimum dissemination and inhalation.[49]

Libya

There is little open-source information available on the current status and sophistication of Libya's BW programs. In its 1997 Annual Report to

Congress, *Adherence to and Compliance with Arms Control Agreements*, ACDA reported that there is evidence suggesting that Libya is seeking to acquire the capability to produce BW agents and has the expertise to manufacture limited quantities of biological production equipment for a BW program. Additionally, although the current Libyan BW program is in the research and development stage, the Libyan government is trying to move the program towards weaponization of BW agents.[50] Indicating that Libya may have made progress towards weaponizing BW agents, the CNS assessment of worldwide BW programs contains the following statement from a Russian source: "There is information indicating that Libya is engaged in initial testing in the area of biological weapons."[51]

North Korea

Similar to the case of Libya, there is minimal discussion in unclassified sources about North Korea's BW activities. However, unlike Libya, as Seth Carus observes, North Korea has been conducting BW research since the early 1960s and most likely has capabilities equal to or greater than Iraq's. Carus has rank ordered the rogue nations' competence in waging biological warfare from highest to lowest as North Korea, Iraq, Iran, Syria, and Libya.[52] The CNS assessment, using DoD and Russian intelligence sources, is that North Korea possesses the biotechnical infrastructure to support a limited BW effort and is conducting military applied research on anthrax, cholera, plague, smallpox, botulinum toxin, hemorrhagic fever, typhoid, and yellow fever.[53] Recently, the Japanese Defense Agency Chief, Hosei Norota, stated that there were several factories in North Korea that were producing "toxic gas and germs" that could be weaponized.[54] South Korea's 1998 Defense White Paper reports that by 1980, North Korea had succeeded in producing bacterial and viral BW agents, had completed live experiments with these weaponized agents by the late 1980s, and is suspected of maintaining several facilities for producing BW agents and biological weapons.[55]

Syria

Syria has very strong motivations for developing WMD and missile delivery systems. First and foremost, Syria views Israel as an aggressive and expansionist state seeking to fulfill its Biblical promises of occupying

the lands from the Nile to the Euphrates Rivers as evidenced by Israel's development and possession of nuclear weapons, its heavy armored ground forces, and its powerful air force which conducted a devastating strategic bombing campaign against Syria during the 1973 war. Consequently, missile-delivered WMD serve as a deterrent to balance Israel's nuclear capabilities and counter the threat posed by Israel's formidable ground and air forces.[56] Concerning its BW capabilities, a U.S. government official briefed in 1995 that Syria's Damascus Biological Research Facility is conducting BW research on anthrax, cholera, and botulinum toxin. Researchers are receiving foreign assistance (possibly from China), and Syria probably has a production capability for their researched BW agents. Furthermore, their BW program may have reached the weaponization stage.[57] Lastly and of particular note, Syria and Iran are cooperating extensively, both technically and economically, on developing offensive BW weapon systems.[58]

III. Land-Attack Cruise Missiles as BW Delivery Systems

> *States able to couple weapons of mass destruction to delivery systems with longer range or greater ability to penetrate defenses can threaten more nations with higher levels of destruction, and with greater likelihood of success.*
>
> --Office of Technology Assessment, U.S. Congress[59]

Cruise Missile Description

Cruise missile definitions abound in the literature, and no two seem to be the same. A good, fairly comprehensive description of a cruise missile is the following: an unmanned aircraft configured as an antisurface weapon intended to impact on, or detonate over, a preselected surface (land or sea) target; it has an integral means of sustained self-propulsion and a precision guidance system (usually autonomous but possibly requiring limited external input from a human operator); aerodynamic surfaces are used to generate lift to sustain the missile's flight; and the missile autonomously achieves a sustained cruise phase of flight at a predetermined level relative to overflown terrain or water.[60] Given these characteristics, cruise missiles can be considered a subset of armed, unmanned aerial vehicles (UAVs) or standoff weapons.

It is important to note that cruise missiles differ significantly from ballistic missiles. A ballistic missile is an unmanned rocket that is powered only during the initial phase (ascent) of its trajectory, reaches exo-atmospheric heights if it is a longer-range missile, and traverses the majority of its trajectory unpowered (i.e., ballistically). Unlike a cruise missile, ballistic missiles cannot usually be guided after launch. (Some of the more advanced ballistic missile systems are armed with guided reentry vehicles.) Thus, at the risk of oversimplification, a ballistic missile is essentially a rocket, and a cruise missile is an aircraft-like system although it may be rocket-powered. However, most cruise missiles, especially the longer range systems, use air-breathing engines--pulsejet, ramjet, turbojet or turbofan--and can even be propeller-driven. Cruise missiles can fly as slow as 100 kilometers per hour (kph) (62 miles per hour) or at supersonic

speeds greater than Mach 3 (Mach 1 is 1,200 kph at sea level) depending on design and intended mission. Most travel at aircraft-like speeds in the mid- to high-subsonic range. Cruise missile flight ranges span from 20 kilometers (km) to over 3,000 km.[61] Their flight profiles also vary widely. Some fly at high altitudes for fuel savings and increased range, then descend to approach the target; others fly the entire profile at low altitude. The more sophisticated cruise missiles produced by the U.S., Russia, and France can fly courses of varying altitudes and azimuths to evade enemy air defenses.

Typically, cruise missiles are categorized according to the intended mission and launch mode instead of their maximum range, which is the classification scheme for ballistic missiles. The two broadest categories are antiship cruise missiles (ASCMs) and LACMs.[62] ASCMs are the most widely deployed cruise missiles; currently they are in the military arsenals of 73 countries.[63] As noted by Seth Carus, they are the most important naval weapons possessed by many of these countries: "The punch provided by ASCMs has made it possible for Third World countries to maintain relatively powerful naval forces that rely on comparatively inexpensive missile-armed patrol boats or small corvettes."[64] ASCMs are designed to strike small targets, i.e., ships at sea at relatively long ranges (up to approximately 500 km) and thus are terminally guided to ships with high accuracy. The terminal guidance systems are active or semi-active radar, radar-homing, infrared, television or home-on-jam.[65]

LACMs are designed to attack mobile or fixed, ground-based targets. The basic components of a LACM are the airframe, propulsion system, navigation and guidance system, and warhead. Basically, the LACM airframe is an elongated, cylindrical missile/aircraft structure with short wings and rudders and constructed from metals and composite materials. The propulsion system (rocket or airbreathing engine) is located in the rear; the navigation and guidance system is located in the front; and the fuel and warhead are typically located in the midbody.[66] (See Figure 1.) Guidance of a LACM is usually a three-phase process: launch, midcourse, and terminal guidance. During launch, the inertial navigation system (INS) guides the LACM. In the midcourse phase, a radar-based terrain contour matching (TERCOM) system and/or satellite navigation system (such as the U.S. GPS or Russian GLONASS) correct for the inherent

inaccuracies of the INS.[67] Upon entering the target area, the terminal guidance system is used and consists of one, or a combination, of the following: GPS/GLONASS, TERCOM with more accurate terrain contour digital maps, Digital Scene Matching Correlator (DSMAC) or a terminal seeker (optical- or radar-based sensor).[68] The mission ranges of LACMs currently in the military arsenals around the world span from 50 to more than 3,000 km, with most designed to travel at high subsonic speeds. Figure 2 is a sketch of LACMs produced by various countries.

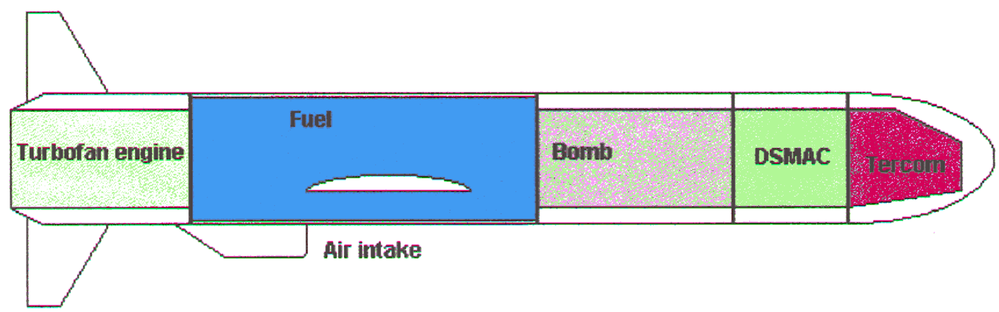

Figure 1. Schematic of the Components of a Land-Attack Cruise Missile

Source: Marshall Brain, "How Cruise Missiles Work," n.p.; on-line, Internet, 25 March 2000, available from http://www.howstuffworks.com/cruise-missile.htm.

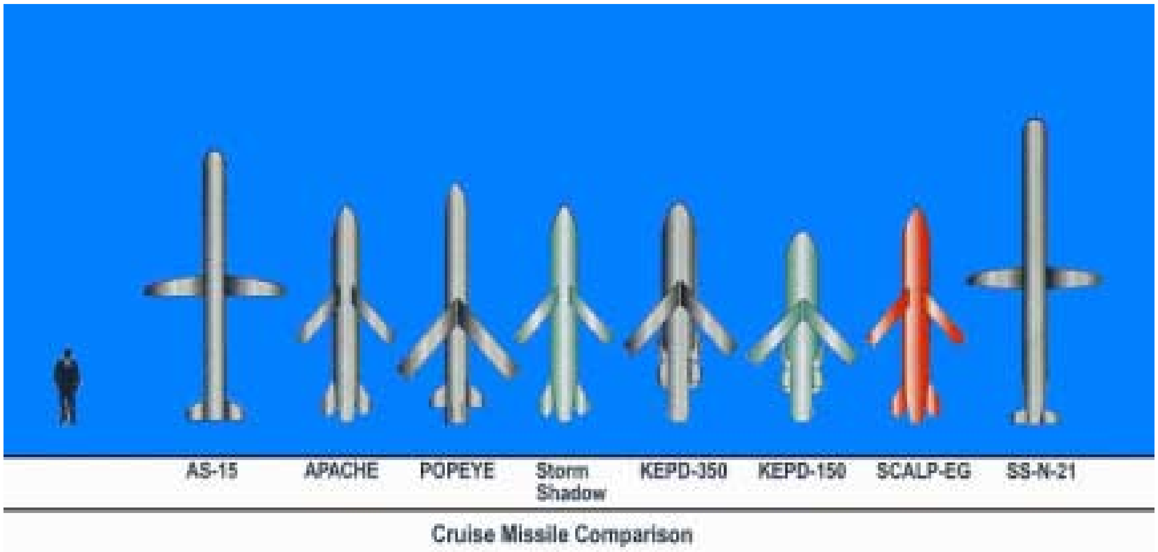

Figure 2. Land-Attack Cruise Missiles of Various Countries

Source: National Air Intelligence Center, *Ballistic and Cruise Missile Threat,* NAIC-1031-0985-99 (Dayton, OH: Wright-Patterson Air Force Base, April 1999), 16.

Cruise Missile Technologies

Coinciding with the "eye-opening" performance of the U.S. TLAMs during the 1991 Persian Gulf War was the beginning of the elimination of substantial technological barriers to Third World countries producing accurate LACMs. Specifically, until the late 1980s, accurate LACMs required sophisticated guidance and navigation technologies--stand-alone, accurate and complex INS, TERCOM and DSMAC--that were well controlled by the Missile Technology Control Regime (MTCR) and thus only available to a few countries such as the U.S., UK, Soviet Union, and France.[69] Now there are critically enabling technologies available commercially that will allow rogue states to acquire militarily as well as politically effective LACMs: precision navigation and guidance technologies (GPS, Differential GPS (DGPS), GLONASS); mission

planning tools (high-resolution (1 meter (m)) satellite imagery and sophisticated Geographical Information Systems (GIS)); high-efficiency, reduced-volume airbreathing engines; more efficient fuels; and composite and low-observable materials.

The commercial availability of accurate satellite navigation updates has allowed Third World countries to leapfrog probably 15 years of development for long-range, fairly accurate LACMs. Relatively inaccurate and widely available $50,000 INS systems can now be combined with low-cost GPS receivers (few hundred dollars at most) to achieve the navigational accuracies of stand-alone, fairly accurate INS systems produced only for Western commercial aircraft and costing roughly $150,000.[70] GPS, DGPS, and GLONASS receivers can be incorporated into all guidance phases of a LACM's flight--launch, midcourse, and terminal. Used in combination, these technologies allow Third World countries to develop LACMs that are robust with respect to GPS degradation and can deliver a payload to within a few meters of the intended target. Commercial DGPS systems are available worldwide and can improve the accuracy of GPS Coarse/Acquisition (the GPS signal available to all users and providing accuracies around 30 m) guidance by an order of magnitude.[71] Additionally, GLONASS, used in conjunction with GPS, improves robustness and accuracy of the guidance system. Honeywell and Northwest Airlines have developed and tested integrated GPS-GLONASS receivers for commercial airline use and have achieved accuracies below 20 m.[72]

GPS, DGPS, and GLONASS guidance technologies provide sufficient LACM accuracies for delivery of both conventional and NBC payloads without the need for a Third World country to employ TERCOM- or DSMAC-like systems which require extensive digital maps. However, a Third World country may want to develop a LACM that flies at very low altitudes and maximizes terrain masking in order to increase in-flight survivability and penetration of air defenses. Such low-altitude flight capabilities would require accurate digital map making capabilities that, until recently, were prohibitively costly. Now such capabilities are commercially available and within affordable ranges for some lesser developed countries. A Third World country can purchase 1-m resolution

satellite imagery, add accurate GPS/DGPS position information with GIS, and produce very accurate, 3-D digital maps.[73]

Other LACM-enabling technologies are the increasingly efficient fuels and turbojet and turbofan engines available on the international marketplace that provide Third World countries the capability of producing cruise missiles with ranges of at least 1,000 km.[74] Additionally, commercially available radar absorbing structures, materials, and coatings along with infrared suppression techniques can greatly reduce the signatures of a Third World country's cruise missiles. Incorporation of these technologies into LACMs significantly and disproportionately complicates U.S. and allied air defense efforts should these LACMs be used in regional conflicts.

Desirable Attributes of Land-Attack Cruise Missiles

Besides accessibility to the technologies as described above, there are many advantageous characteristics of LACMs as weapon systems that motivate lesser developed countries with limited monetary resources to acquire or develop them as part of a balanced military strike force which includes combat aircraft, ballistic missiles, and cruise missiles. One particularly desirable feature is their relatively small size, especially compared to aircraft and ballistic missiles. Coupled with the LACM's aerodynamic flight to the target (as opposed to ballistic dynamics), which eliminates the need for stabilization at launch, LACMs are easily deployable on a wide variety of platforms--ships, submarines, aircraft, and small, fixed or mobile land-based launchers. This flexibility in carrier platform translates directly into increased survivability before launch. Unlike a combat aircraft, a LACM is not restricted to operating from airfields which, during conflict, are extremely vulnerable to preemptive attacks by the adversary. Also, on land, LACMs are much easier to hide from opposing forces and more mobile than ballistic missiles (no pre-surveyed launch site required), further enhancing a rogue nation's ability to conduct “shoot and scoot” launches which the Iraqis executed with great success against the U.S. during the Persian Gulf War in spite of the U.S.'s intensive “Scud hunt” operations.

A very interesting and potential sea-based exploitation of the LACM's small size has been discussed by Dennis Gormley.[75] Even a bulky, fairly

large 500- to 700-km range LACM (8.5 m in length, 0.8-m body diameter, 2.4-m wingspan), that a rogue nation such as Iran might be expected to indigenously produce by the 2005-2010 timeframe (discussed in more detail in chapter IV), can fit into a standard 12-m shipping container along with a small erector constructed for launching the LACM directly out of the container. The international maritime fleet consists of thousands of commercial ships using these containers, and on any given day, about 1,000 ships are transiting the Atlantic. Only four percent of these ships are scrutinized by customs upon docking in U.S. ports. Furthermore, the U.S. ports handle 13 million shipping containers annually. A range of 500 to 700 km allows a rogue country deploying such a ship-based LACM to remain outside the 200-mile territorial waters zone and strike the majority of the key population and industrial centers in both Europe and North America. Such a threat is extremely challenging, posing both a very difficult monitoring challenge for the intelligence community and challenges for establishing adequate defenses. Gormley states in a Spring 1998 *Survival* article that "the non-governmental 'Gates Panel', in reviewing NIE [National Intelligence Estimate] 95-19, . . . concluded that not nearly enough attention was being devoted to the possibility that land-attack cruise missiles could be launched from ships within several hundred kilometres of U.S. territory."[76] Perhaps in response to this criticism, the Intelligence Community's most recent (September 1999) unclassified NIE on the ballistic missile threat to the United States through the year 2015 states:

> A commercial surface vessel, covertly equipped to launch cruise missiles, would be a plausible alternative for a forward-based launch platform. This method would provide a large and potentially inconspicuous platform to launch a cruise missile while providing at least some cover for launch deniability.[77]

Another benefit of the LACM's relatively small size and design is the resultant increased survivability of the missile during flight. Because of its small size, a LACM has inherently low visual, infrared (IR) and radar signatures. The reduced radar observability, referred to as a reduced radar cross section (RCS), makes the missile difficult for air defense radars to

detect, identify, track and engage, especially compared to the conventional combat aircraft in a rogue state's arsenal. Complicating the problem for the air defenses, a LACM can readily be made more difficult to detect with the application of low-observable materials. The simplest approach would be to apply radar absorbing coatings to the airframe surface and incorporate an IR reduction cone around the engine. The airframe could also be constructed with radar absorbing polymers and nonmetallic composites to minimally reflect radar energy. Or, requiring the most technical skill, the shape, structure, composition, and integration of subcomponents of the LACM could be designed and constructed from the beginning with very low-observability as the goal.

The impact of reduced observability can be dramatic because it reduces the maximum range from missile defenses that an incoming LACM can be detected, resulting in minimal time for intercept. To illustrate, a conventional combat aircraft such as an F-4 fighter has an RCS of about 6 square meters (m^2), and the much larger, but low-observable B-2 bomber, which incorporated advanced stealth technologies into its design, has an RCS of only approximately 0.75 square meters.[78] A typical cruise missile with UAV-like characteristics has an RCS in the range of 1 m^2; the U.S.'s Tomahawk air-launched cruise missile (ALCM), designed in the 1970s utilizing the fairly simple low-observable technologies then available, has an RCS of less than 0.05 m^2. The U.S. AWACS radar system was designed to detect aircraft with an RCS of 7 m^2 at a range of at least 370 km. Using the physics of radar detection, which dictates that detection range varies with the object's RCS raised to the one-fourth power, the AWACS radar could detect the typical, non-stealthy cruise missile at a range of at least 227 km, and the stealthy cruise missile would approach air defenses to within a range of 108 km before being detected. Traveling at a speed of 805 kph (500 mph), air defenses would have only 8 minutes to engage and destroy the stealthy missile and 17 minutes for the non-stealthy missile. Furthermore, a low-observable LACM can be difficult to engage and destroy even if detected. According to Seth Carus, a Soviet analyst assessed that cruise missiles with RCSs of 0.1 m^2 or smaller were difficult for surface-to-air missile (SAM) fire control radars to track.[79] Consequently, even if the SAM battery detects the missile, it may not acquire a sufficient lock on the target to successfully intercept. Even IR

tracking devices may not detect low-observable LACMs, and IR-seeking SAMs may not home in on the missile. To further thwart engagement, a LACM could employ relatively simple countermeasures such as chaff and decoys.

Further increasing its survivability, a LACM can avoid detection by air defenses through programmed flight paths on which the LACM approaches the target at extremely low altitudes, blending its small signatures into the large ground clutter, and also takes advantage of terrain masking. Technologies that enable “terrain hugging” flight--radar altimetry, precision guidance and satellite navigation, computerized flight control, high-resolution satellite imagery, and digitized terrain map making via sophisticated GIS--are becoming increasingly available from commercial sources at affordable costs. These technologies also enable the longer-range LACMs to be programmed to fly lengthy and circuitous routes to the target to minimize their exposure to air defense systems and perhaps eliminate the exposure altogether.

Another approach to penetrate air defenses that is afforded by the operational flexibility of the LACM is to launch multiple missiles against a target simultaneously from varied directions, overwhelming air defenses at their weakest points. Also, a rogue state could launch both theater ballistic and cruise missiles to arrive simultaneously at the designated target. The different characteristics of these two approaching missiles--high-altitude, supersonic ballistic trajectory of the ballistic missiles and low-altitude, subsonic flight of the cruise missiles--could stress and overwhelm the capabilities of the most advanced air defense systems. A Joint Chiefs of Staff official interviewed by an *Aviation Week & Space Technology* reporter commented: “A sophisticated foe might be able to fire 20 or 30 [Scud-type] battlefield ballistic missiles, followed by aircraft that pop up to launch waves of cruise missiles. The resulting problem for U.S. defenders would be staggering in complexity.”[80] And a former senior planner for Operation Desert Storm commented: “During Desert Storm, if the Iraqis could have fired even one cruise missile a day--with a two-city block [accuracy]--into the headquarters complex in Riyadh, we would have been out of commission about half the time.”[81] Complicating the defender's situation even further, the attacker could time the LACM strikes to coincide with the return of the defender's aircraft, thereby greatly

complicating an already difficult problem for the defender of identifying friend from foe. As stated by a senior official at the Pentagon's Joint Theater Air and Missile Defense Office, “The challenge with ballistic missiles is hitting them . . . . With cruise missiles, it's figuring out whether it's friendly or not.”[82]

Enabled by the increasing commercial availability of advances in key technologies for all components of a LACM--airframe, propulsion, guidance and navigation, and warhead--the combined accuracy and range attributes of LACMs now exceed those of ballistic missile systems at far less cost per weapon system. For example, LACMs can be developed with similar-sized warheads and ranges as those of substantially more complex ballistic missiles but at less than half the cost (approximately $250,000 or less versus $1,000,000) and with at least 10 times the warhead delivery accuracy (10 - 100 m circular error probable (CEP) compared to 1000 - 2000 m CEP).[83] By carrying different warheads, a LACM provides a rogue nation more cost-effective capabilities for deep strike of heavily defended targets such as airfields, ports, staging areas, troop concentrations, amphibious landing areas, logistics centers, and command, control, communications and intelligence nodes. Additionally, since the accuracy of the LACM is significantly better than a similar-range ballistic missile, the probability of destroying or damaging the target is much higher. Furthermore, the range of a LACM is extended by the range of its platform which gives it the capability to attack targets well beyond the range of a comparable ballistic missile. Also, as is the case for ballistic missiles, the LACM attacks are carried out without risking the loss of aircrew lives.

As a delivery system for WMD, LACMs are ideally suited for disseminating BW agents. As would be the case for aircraft dissemination, a subsonic LACM, using an aerosol sprayer embedded in its wings and built-in meteorological sensors coupled to the guidance and control computer, could alter its flight profile and release a line source of BW agent tailored to the local topography, micro-meteorological conditions and shape of the target, thus maximizing the resultant lethal area of the BW payload. The advantage of employing a LACM for BW agent delivery as opposed to an aircraft is that a pilot's life is not risked; the disadvantage is forfeiture of pilot improvisation. According to

Gormley, “The lethal areas for a given quantity of CBW [chemical or biological warfare agents], and this is a very, very conservative calculation, are at least ten times that of a ballistic missile delivery program. This judgment reflects the results of extensive modeling and simulation.”[84] In Gormley's simulation, an optimal pattern of distribution of CBW agents using submunitions was assumed for ballistic missile delivery. For LACM delivery, both worst-case and best-case distributions were averaged for the comparison. The increased lethality area for a LACM-delivered CBW payload is primarily attributable to the aerodynamic stability of the LACM and the capability of distributing the CBW agent payload as a line source. It is interesting to note that the U.S. investigated using the Snark cruise missile for delivery of BW and CW agent payloads as early as 1952, and through the early 1960s, funded projects developing dissemination systems for cruise missiles and drones.[85]

In addition to achieving significantly more effective dissemination of BW agents, subsonic LACM delivery is simply technically less challenging than supersonic ballistic missile delivery. There are considerable technical difficulties with packaging BW agents within a ballistic missile warhead and ensuring that the agent survives and is disseminated as an aerosol at the correct height above the ground.[86] The reentry speed is so high during the descent phase of the ballistic missile's trajectory that it is difficult to distribute the agent in a diffuse cloud or with the precision to ensure dissemination within the inversion layer of the atmosphere. Also, the high thermal and mechanical stresses generated during launch, reentry and agent release may degrade the quality of the BW agent. U.S. tests have shown that, without appropriate agent packaging, less than five percent of a BW agent payload is viable after flight and dissemination from a ballistic missile.

There are a few other operational features of LACMs that may make them economically and militarily appealing to a lesser developed country building strike capabilities with very limited defense resources. Compared to aircraft and ballistic missiles, LACMs require less support infrastructure and have lower operations and maintenance costs. They can reside in canisters, which makes them significantly easier to maintain and operate in

harsh environments. Furthermore, since they are unmanned, the need for expensive pilot and crew training is eliminated.

IV. Proliferation Pathways for Land-Attack Cruise Missiles

> *Until recently, the problem of cruise missile proliferation centered on antiship--not land-attack--systems. But now there is growing concern that the developing world will acquire land-attack cruise missiles. . . . Should such strike systems proliferate into the arsenals of rogue states, they could present serious challenges to U.S. force planners in a variety of military contingencies.*
>
> --K. Scott McMahon and Dennis M. Gormley[87]

In estimating the timeframe by which rogue nations may acquire threatening LACMs as BW payload delivery systems, many factors must be considered. Three important factors were discussed in the previous chapters: (1) the motivations and incentives for countries to acquire WMD (biological weapons, in particular); (2) the operational and economic advantages of LACMs as part of a precision strike force; and (3) the commercial availability and proliferation of key enabling technologies for accurate, long-range LACMs. Another major factor is the multiple and varied acquisition paths available to rogue nations. Three major proliferation pathways that are likely to be used by rogue states are: (1) the direct purchase of complete LACMs from another country; (2) indigenous development of LACMs, with or without outside assistance; and (3) conversion of ASCMs or UAVs to land-attack weapon systems.

Direct Purchase

The quickest way for a rogue country to obtain LACMs is to purchase them directly from producer nations. In the past this acquisition path was unavailable because the only producers of complete LACM systems were France, Russia, and the U.S., and they did not export their missiles. However, within the next decade, the number of countries besides the U.S. that produce LACMs will jump from two to nine.[88] Table 4 summarizes this rapid growth in the number of LACM-producing countries

and the systems currently under development. Most of the LACMs under development will incorporate low-observable technologies, have modular

Table 4. Non-U.S. Land-Attack Cruise Missiles

System	Country	Launch Mode	Warhead Type	Maximum Range (kilometers)	Initial Operational Capability
Chinese cruise missile	China	Undetermined	Conventional or nuclear	Undetermined	Undetermined
APACHE-A	France	Air	Conventional/ submunitions	160+	1999
SCALP-EG	France	Air & ship	Conventional/ penetrator	480+	2002
KEPD-350	Germany/ Sweden/Italy	Air & ground	Conventional/ unitary	350+	2002
KEPD-150	Germany/ Sweden/Italy	Air & ship	Conventional/ unitary or submunitions	160+	2002
Popeye Turbo	Israel	Air	Conventional/ unitary	320+	2002
AS-15	Russia	Air	Nuclear	2,400+	Operational
SS-N-21	Russia	Submarine	Nuclear	2,400+	Operational
Russian conventiona l cruise missile	Russia	Undetermined	Conventional/ unitary or submunitions	Undetermined	Undetermined
MUPSOW	South Africa	Air & ground	Conventional/ unitary or submunitions	200+	2002
Storm Shadow	United Kingdom	Air	Conventional/ penetrator	480+	2002

All ranges are approximate and represent the range of the missile only.

Source: National Air Intelligence Center, *Ballistic and Cruise Missile Threat*, NAIC-1031-0985-99 (unclassified) (Dayton, OH: Wright-Patterson Air Force Base, April 1999), 20.

designs which readily facilitate range and payload modifications, will have multiple navigation and warhead options and will be deployable from a variety of platforms.[89] Many of these countries, including France and Russia, will probably make their LACMs available for export, especially given the increasing desires of the more industrialized countries to export advanced weapon systems because of shrinking domestic military sales during the recent years of declining defense budgets. Market analysts project that 6,000 to 7,000 LACMs could be sold by 2015, excluding U.S., Russian, and Chinese sales.[90]

Halting the export of LACMs will be extremely difficult because of the serious shortcomings of the MTCR, the only international export control arrangement that actively attempts to control the proliferation of cruise missiles, their subcomponents and key enabling technologies.[91] MTCR members voluntarily pledge to adopt the Regime's export guidelines and to restrict the export of items contained in the Regime's annex. Category I of the MTCR annex requires member states to make a strong presumption to deny exports of UAVs and cruise missiles (and their key subsystems, technologies and production facilities) carrying 500-kg payloads to ranges of 300 km or more. Category II urges member discretion in exporting dual-use components and complete missiles capable of 300-km ranges with any payload.

From a LACM proliferation viewpoint, the most serious problem with the MTCR is that there is no approved methodology among the MTCR members for determining the Category I range and payload threshold for cruise missiles.[92] Determining a cruise missile's range is not straightforward because of flight profile variability and ease in trading off range and payload to improve mission performance. Therefore, judging whether a LACM is Category I or Category II is very difficult and leads to different interpretations and disagreements among the members, thus weakening the Regime's ability to control LACM export. Additionally, the MTCR places only very weak controls on the export of low-observable technologies. The Regime also permits exports to support both civilian and military manned aircraft. The guidance systems, INSs, flight controls, autopilots, avionics, jet engines, and other components and technologies for many of these aircraft are usable in cruise missiles.[93] Finally, there are no provisions in the Regime for enforcement of its terms or sanctions for

violations. Essentially, the door is wide open for lesser developed countries to purchase highly-capable LACMs, and unless international controls on cruise-missile exports can be strengthened, this pathway may become the major source of advanced LACM proliferation.

Although no known direct transfers of complete LACMs have yet occurred, France is considering exporting a 140-km range, 520-kg payload variant of its very sophisticated, state-of-the-art, stealthy Apache LACM.[94] The Apache is modular in design and will be produced in three variants, all of which use the same 1,200-kg airframe. Figure 3 shows the layout and design of the Apache. Thus, no matter what the advertised range and payload, the 1,200-kg airframe being considered for export can carry a 500-kg payload beyond 300 km, clearly making any variant of the Apache an MTCR Category I cruise missile. However, to date, the U.S. has been unsuccessful in convincing the French that the advertised Apache variant is Category I.[95] With regard to stealth, the Apache is Tomahawk-level or better. Additionally, it uses a millimeter-wave radar system similar to TERCOM allowing for low-altitude flight profiles, incorporates GPS midcourse guidance updates, employs a terminal seeker with a radome (which reduces the active signature of the terminal guidance system), and has a reported accuracy of 1 to 2 m CEP.[96] Gormley warns: "Should such a system fall into the wrong hands, it would provide not only design insight into an advanced-technology missile, but also a robust threat system capable of challenging the most advanced air defences."[97] Just as disturbing is the precedent that the French, charter members of the MTCR, would establish for fellow members if they are ultimately successful in exporting the Apache. Some of the other MTCR members may follow the French lead and export LACMs in violation of Category I. For example, the Spanish company CASA initiated a program to develop and produce a LACM with characteristics similar to the French Apache and has stated its intentions to compete its LACM against the Apache in what it sees as a lucrative export market.

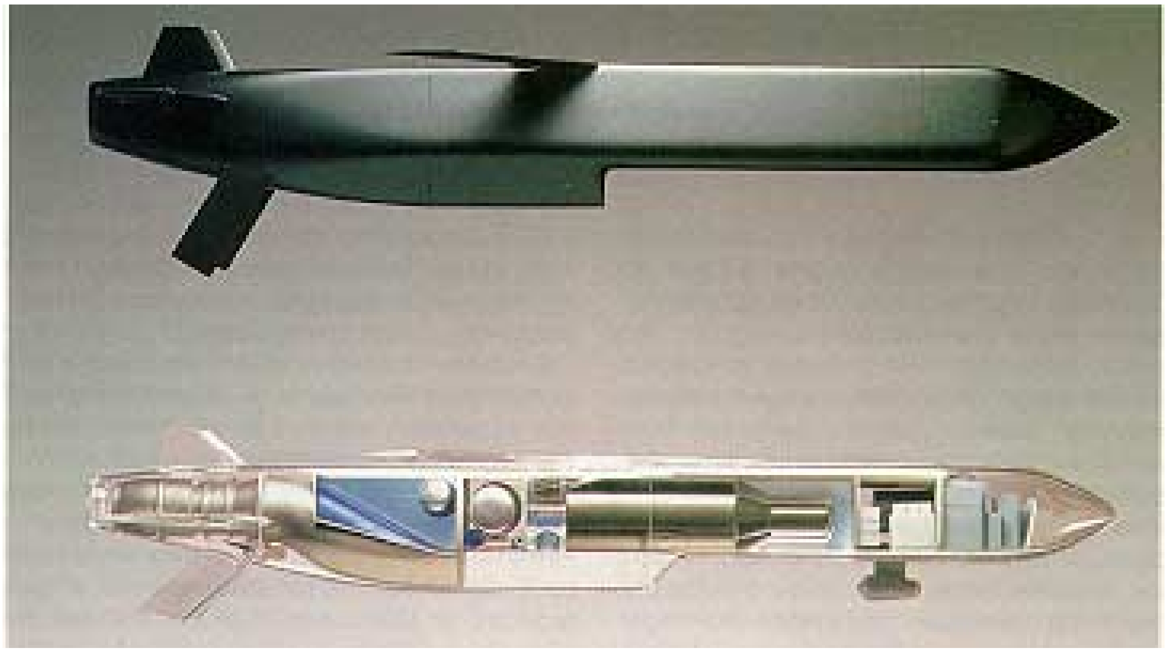

Figure 3. French Apache Land-Attack Cruise Missile.

Source: Jean-Paul Philippe, “Matra to Develop APTGD Missile: A New 'Stealth' Cruise missile for France,” *Military Technology* 19, no. 2 (February 1995): 60.

The Russians are also trying to export sophisticated LACMs. At the Moscow Air Show in 1992, Russia offered for sale a shorter-range version, 500-600 km with a 410-kg conventional payload (just under the MTCR Category I payload threshold), of their 3,000-km AS-15 strategic LACM. This missile, referred to as the Raduga Kh-65SE, incorporates INS, GLONASS updates and TERCOM-like systems to achieve a reported accuracy of less than 20 m. Figure 4 is a marketing brochure for this potential Russian LACM export. Subsequently, at the 1993 IDEX Defense Exhibition in Abu Dhabi, the Russians displayed a further scaled-down version of the Kh-65SE with a quoted range of 280 km, slightly below the MTCR Category I range threshold of 300 km.[98] Taiwanese sources reported that the Russians tried to sell this LACM to the Chinese, but it is not clear whether or not any sales were made.[99] With a Kh-65SE

China would have access to advanced Tomahawk-like LACM technologies such as navigation and guidance, stealthy airframe design, and low-volume, high-efficiency engines. Also, apparently the Kh-65SE would only need modifications to carry additional fuel and could then achieve ranges up to 3,000 km.[100]

Figure 4. Marketing Brochure for Russia's Kh-65SE Cruise Missile.

Source: K. Scott McMahon, "Cruise Missile Proliferation: Threat, Policy, and Defenses," presentation to the American Institute of Engineers Conference on Missile Defense, 5 March 1999.

Given the Russians' desperate economic situation and the need for hard currency, one can expect that they will continue to vigorously market their LACMs as the demand from lesser developed countries increases.

Even more ominous than the current situation with the French and Russian attempted maneuverings around the MTCR to export advanced LACMs, are recent developments in China. China is reported to have developed and recently deployed a short-range LACM, designated YJ-22, with a range of 400 km, estimated CEP of 50 m or less, integrated INS and GPS/GLONASS guidance and navigation, and capable of being launched from air, land or sea platforms. It is believed to be an advanced development (modified airframe and better engine) of the YJ-2/C-802 turbofan-powered ASCM, which is itself a reverse-engineered version of the exported French Exocet ASCM.[101] Additionally, it was reported in the August 14, 1999 Hong Kong *Sing Tao Jih Pao Daily* (Internet version) that China has developed a "killer" LACM, similar to the U.S. Tomahawk LACM, with the following specifications and characteristics: 2,000-km range; 5-m CEP; can fly as low as 15-20 m above land or water; carries conventional or nuclear payloads; can be land- or sea-launched; and uses digital maps and topography matching, inertial guidance, GPS auxiliary correction, and other auxiliary guidance.[102] Both Chinese cruise missiles were likely developed with the aid of Russian and Israeli cruise missile technologies exported to China. In 1995, Dr. Chong Pin Lin, a Republic

of China government official and People's Liberation Army expert, stated that China had purchased Russian cruise missile manufacturing technology and had hired a Russian cruise missile design team, locating the team in the Shanghai area. It is also believed that China has had access to the cruise missile expertise of the Russian Raduga and NRP Machinostroyenia Bureaux teams in the areas of radar and IR signatures control and may have received help from the Israelis in these same areas.[103] China has presumably acquired a U.S. TLAM that crashed in Afghanistan during the 1998 strikes against Osama bin Laden.[104] Lastly, China and Israel are co-developing an air-launched, estimated 385-km range, 450-kg payload LACM based on the Israeli Delilah anti-radiation attack drone, which probably incorporates INS, GPS, and IR navigation and guidance.[105] Unfortunately, even though they are stated adherents to the MTCR, the Chinese have a well-documented history of ignoring the restrictions of the MTCR and freely exporting missiles of all types.

As a final example of countries that have LACMs and are willing to export them, Taiwan's Hsiung Feng II, 170-km range, 75-kg payload, turbojet-powered cruise missile can be used both against ships and land targets. The Taiwanese reverse-engineered this missile from the U.S. Harpoon ASCM. They have offered the Hsiung Feng II for export.[106] The bottom line is that France, Russia, China, Israel, and others can proliferate LACM technologies and the missiles themselves within (or outside) the guidelines of the MTCR. Therefore, the direct purchase of advanced LACMs is a serious proliferation concern and clearly has the potential of becoming a major source of LACM proliferation to rogue nations and other Third World countries.

Indigenous Development

Although indigenous development is the most lengthy and technically difficult proliferation pathway, many countries pursue this route for acquiring LACMs in order to be self-sufficient and independent from foreign suppliers. Also, they desire to be a player in the lucrative international military sales arena. As Amy Truesdell, a researcher at the Centre for Defence and International Security Studies, University of Lancaster, UK, notes, "Indeed, China, North Korea, Iran, and Iraq have all

proven that they will invest whatever it takes to decipher imported cruise-missile technology to use as the basis for indigenous programmes."[107]

Greatly assisting these countries and others in their endeavors is the rapidly decreasing investment, both in resources and time, required for indigenous development as a result of the globalization of the civilian and military aircraft industries. The airframe structures, guidance and navigation systems, and propulsion systems for manned aircraft and cruise missiles are basically interchangeable. Furthermore, there currently exists a "buyer's market" in the worldwide aerospace industry. Developing countries are aggressively taking advantage of this opportune climate to acquire supersonic aircraft with turbojet and turbofan engines, and to secure offsets with their purchases that provide them indigenous aircraft maintenance and production facilities.[108]

Another factor shortening the indigenous development cycle is the set of readily available cruise missile enabling technologies discussed previously. Truesdell aptly notes: "When one considers the fact that the cost of GPS receivers continues to plummet, computing power continues to grow, digital mapping software is readily available, and the supersonic aircraft now being exported are propelled by turbojet and turbofan engines, it is clear that the necessary ingredients for indigenous land-attack cruise missile manufacturing programmes currently exist."[109] The willingness of countries such as Russia, China, and Israel to provide foreign assistance also demonstrably affects lesser developed countries' abilities and timeframes to acquire indigenous LACM development and production capabilities. Commenting on the seriousness of ballistic and cruise missile proliferation, Donald Rumsfeld stated:

> Technology transfer is happening across the globe. People who want to get access to these capabilities can in fact do so. . . . Every country can get some kind of help from somebody, and to the extent they want it, they can get it."[110]

Lastly, the lesser developed countries are increasingly cooperating in a substantial fashion among themselves in the acquisition of strategic and tactical weapon systems. Dr. William Graham, former Director of the White House Office of Science and Technology Policy and a member of the 1998 Congressionally-directed Rumsfeld Commission, believes

that, ". . . if all help from Russia, China, the U.S., Europe, and Asia were ended today and the developing world was left to its own devices, they would still move forward quite rapidly because among them they have very substantial information, data, facilities, capabilities, and intelligence."[111] Graham also notes that, at any given moment, the West is educating approximately 100,000 foreign graduate students, many of them from the countries the U.S. is trying to prevent from developing long-range offensive missiles.

Of the five currently designated rogue nations, the most unclassified information on cruise missile programs and capabilities for indigenous manufacture of LACMs exists for Iran, Iraq, and Syria. Table 5 summarizes the cruise missiles in the rogue nations' arsenals and those that are being developed indigenously. Iran has acquired a wide variety of short-range, sophisticated ASCMs from multiple exporters. Some of these can also be used in the land-attack role. Since 1989 and with Chinese assistance, Iran has indigenously produced the HY-1 Silkworm and HY-2 Seersucker ASCMs.[112] Additionally, Iran may also be establishing production facilities for ASCMs based on the Chinese C-801 and C-802 cruise missiles. In 1995, Tehran announced it had test-fired an indigenously produced ASCM. Iran is currently developing an improved

Table 5. Rogue Nations' Cruise Missiles and Development Programs

Country/System	Supplying Country	Type	Launch Method	Maximum Range (km)	Payload (kg)	Status
Iran						
YJ-1/C-801	China	AS	A/G/S	40	165	In Service
AS-11 Kilter	Russia	LA/AS	A	50	130	In Service
AS-9 Kyle	Russia	LA/AS	A	90	200	In Service
YJ-2/C-802	China	AS	A/G/S	95	165	In Service
HY-2 Silkworm	China/ North Korea	AS	G/S	95	513	In Service
SS-N-22 Sunburn	Ukraine	AS	S	110	500	In Service
RGM-84A Harpoon	U.S.	AS	S	120	220	In Service
HY-4/C-201	China	AS	A/G/S	150	500	In Service
HY-2 (Mod) Silkworm	Domestic/ China	AS	G/S	450	500	Development
Iraq						
YJ-1/C-801	China	AS	A/S	40	165	In Service
AS-11 Kilter	Russia	LA/AS	A	50	130	In Service
Exocet AM-39	France	AS	A	70	165	In Service
FAW 70/150/200	Domestic	AS	G/S	70/150/200	500	In Service
Armat	France	LA	A	90	160	In Service
HY-2 Silkworm	China	AS	G/S	95	513	In Service
C-601/Nisan 28	China	AS	A	95	500	In Service
AS-6 Kingfish	Russia	LA/AS	A	180	1,000	In Service
AS-5 Kelt	Russia	LA/AS	A	400	1,000	In Service
AS-4 Kitchen	Russia	LA/AS	A	400	1,000	In Service
Ababil	Domestic	LA	A	500	300	Development

North Korea						
SS-N-2a/P-15 Styx	Domestic	AS	S	43	513	In Service
HY-1/HY-2 Silkworm	Domestic	AS	G/S	95	513	In Service
Modified Silkworm	Domestic	AS	G/S	160+	Unk	Development
Syria						
SS-N-2c Styx	Russia	AS	S	85	513	In Service
SS-N-3b Sepal	Russia	AS	G/S	450	1,000	In Service

AS: Antiship LA: Land-Attack

A: Air G: Ground S: Sea

Source: Humphry Crum Ewing et al., *Cruise Missiles: Precision & Countermeasures*, Bailrigg Memorandum 10 (Lancaster, United Kingdom: Centre for Defence and International Security Studies, 1995), 34-41. Center for Nonproliferation Studies, Monterey Institute of International Studies, "Cruise Missiles and Unmanned Aerial Vehicles Deployed in the Middle East," n.p.; on-line, Internet, 8 February 2000, available from http://www.cns.miis.edu/research/wmdme/crui_dep.htm.

Silkworm system with a range of 450 km at its Chinese-built plant at Bandar Abbas, again with Chinese assistance. This missile, if developed as a land-attack variant, which some sources indicate the Iranians have claimed, would be able to strike Saudi Arabia and all the Persian Gulf states.[113] An interesting, unconfirmed report from the perspective of Iran's future cruise missile capabilities, is that Iran acquired a U.S. TLAM that was fired at Bosnian targets but did not detonate. If this acquisition actually occurred, Iran, especially with Chinese assistance, would probably be able to reverse engineer a sophisticated LACM. Various assessments indicate that Iran will integrate GPS into guidance systems, develop improved engines for longer ranges and incorporate low-observable technologies in its continuing development and production of cruise missiles. First generation LACMs would probably be based on the Chinese Silkworm and C-802 ASCMs currently fielded by Iran. By 2010, Iran is assessed to be capable of producing long-range cruise missile delivery systems and packaging BW agents in spray tanks within these systems.[114]

Concerning Iraq's indigenous cruise missile manufacturing capabilities, the FAW series of ASCMs are domestically-produced versions of the short-range Chinese Silkworm ASCMs. The FAW 150 and 200 are longer-range (up to 200 km), delta-winged versions of the HY-2 Silkworms. Before the Gulf War, Iraq first revealed its indigenously produced Ababil LACM which was developed from the Italian Mirach-600 remotely piloted vehicle. This system is turbojet powered and has a range of 500 km and payload of 250 kg. Also, before the Gulf War, Iraq had under development a ramjet-powered, Mach 3 cruise missile with a range of up to 800 km.[115] In 1998, UNSCOM discovered that Iraq had been acquiring the 900-km Polish BZM18 UAV with the possible intent of modifying the system for delivery of CBW payloads.[116] A good, overall assessment of Iraq's indigenous cruise missile development and production capabilities is the following:

> Whilst Iraq has the ability to fuse and equip a land attack cruise missile with CBW warheads, it may not have the ability to develop suitable guidance and propulsion systems indigenously. However it may be possible for Iraq to acquire critical technologies--such as turbojet-powered RPVs and guidance systems--on the black market and carry out the necessary integration and modifications using its domestic manufacturing capability.[117]

Reportedly, Syria was particularly impressed with the performance of the U.S. TLAMs during the 1991 Persian Gulf War and is believed to be developing its own cruise missile for future deployment with both conventional and unconventional payloads.[118] First-generation missiles would most likely be developed from currently fielded ASCMs such as the SSC-1b Sepal. However, other LACMs could be produced given Syria's intensified cooperative efforts with Iran. Of particular note, if Iran did acquire the U.S. TLAM from Bosnia, it is very possible that the technical information gleaned from the TLAM was shared with Syria.

Conversion of ASCMs to LACMs

In addition to direct purchase and indigenous development of LACMs, rogue states and other lesser developed nations will likely pursue conversion of ASCMs into longer-range LACMs because of the commercially and readily available LACM enabling technologies and the large number of ASCMs--more than 75,000--that have proliferated worldwide and currently reside in the world's military arsenals. Of the proliferated ASCMs, the older, first-generation Russian Styx and its Chinese derivative, the Silkworm family (HY-1, HY-2 and HY-4), are better suited for modification to LACMs. Because of their relatively large size and simplicity of design compared to the more modern ASCMs such as the French Exocet and U.S. Harpoon, they are inherently easier to modify. Also, the sizable volume provides space for transformation and additional fuel, thus allowing for significant range extension.[119] The most direct route for ASCM conversion into a longer-range LACM consists of transforming the turbojet-powered Chinese HY-4 Sadsack. Although the HY-1 and HY-2 ASCMs could also be converted into LACMs, the transformation would be more complicated and require more sophistication and technical skills, because the HY-1 and HY-2 use liquid-rocket engines which would need to be replaced with turbojets or turbofans. Other desirable features of the HY-4 Sadsack are that it has a range of 150-200 km, carries a payload, of 500 kg, cruises at a maximum speed of 0.78 Mach, and can be air-, ship-, or truck/trailer-launched. The Sadsack is easily accessible to any country and is already in many countries' arsenals. Moreover, China is advertising for export a multipurpose HY-4 variant dubbed the C-201W and is developing an improved HY-4, the XW-41, which is expected to have an increased range of 300 km.[120] Neither of these ASCMs are restricted exports under the MTCR and China is quite willing to sell them to anyone offering to buy.

To investigate how rogue nations such as Iran, Iraq, or Syria and other developing countries could convert an ASCM into a LACM, along with the costs and technical skills required for such a transformation, a team of scientists and engineers conducted a paper study on transforming the HY-4 ASCM into nominal 500-, 700-, and 1,000-km range LACMs for delivery of BW agents.[121] The team consisted of a small number of aeronautical and propulsion engineers, aerosol dispenser and weapons effects

specialists and proliferation analysts. The conversion of the HY-4 into a 300-kg payload, 500-km range LACM/BW (or biocruise) weapon system, which will be called the Biocruise-500, required four modifications: (1) replacement of the autopilot and radar subsystems with a land-attack navigation system costing only an estimated $40,000 and constructed from commercially available GPS-GLONASS integrated receivers, radar altimeter, inertial measurement unit, flight management computer, electronic servos, and DC power system with alternator; (2) installation of extra internal fuel tanks for additional fuel; (3) installation of wing tip sprayers for BW liquid agent release; and (4) development of guidance software for the most efficient dispersal of the agents. The 1,000-km range LACM, the Biocruise-1000, required reduction of the BW payload to 120 kg and the additional and more complicated modification of lengthening the existing HY-4 fuselage to carry more fuel. This paper study led to the conclusion that China, Iran, Iraq, North Korea, and Pakistan possess the ability to convert the HY-4 into Biocruise-500s or 1000s. Furthermore, with limited outside assistance, a resourceful and creative proliferant like Iran could probably produce the Biocruise-1000 within 7 to 10 years. If the outside assistance were more substantial, including experienced technicians, senior engineers, and advanced production equipment, the time might be halved to four or five years. The cost of the Biocruise-1000 was estimated to be $250,000 - $350,000, substantially less than the $500,000 - $1,000,000 price tag for the Iraqi Al Hussein ballistic missile. Obviously, this paper study illustrates the plausibility of rogue nations rapidly acquiring LACMs/BW weapon systems of significant range which could be used to seriously threaten U.S. and allied regional military operations and the U.S. and allied homelands.

V. Summary and Assessment of the Biocruise Threat

> *A number of countries have the wherewithal to develop the capability to launch cruise or ballistic missiles from forward-based platforms, such as a service ship or freighters . . . well before 2010.*
>
> --Col James Ward[122]

From the perspective of a rogue nation facing the formidable conventional military power of the U.S. and its allies, a LACM, especially if equipped with a BW agent payload, is a very politically and militarily cost-effective weapon system. Politically, the mere threat of using a system such as the Biocruise-1000 with a payload of 120 kg of anthrax against a major U.S. or allied city could deter the U.S. from becoming involved in a rogue nation's aggression against a neighbor or bid for regional hegemony. Militarily, such a WMD delivery system, especially if low-observable technologies and simple endgame countermeasures such as chaff and decoys have been incorporated, has a good chance of penetrating air defenses and accurately delivering its payload, thus causing large numbers of casualties. And a weapon system such as the Biocruise-1000 is cost-effective, especially when compared to similar range ballistic missiles and to the costs of conventional combat aircraft. As such, a lesser-developed country with limited defense resources could purchase larger numbers of the LACMs and use them in mass to even further complicate the air defense problem for the U.S. and its allies.

With the commercial explosion of critically enabling technologies for precise navigation and guidance; sophisticated mission planning; low-weight, high-efficiency propulsion; and air defense penetration, the development of a biocruise weapon system is now within the reach of the rogue states. Iran, Iraq, and North Korea have continually demonstrated in the past that they are determined and resourceful acquirers of weapon systems that will provide them with strategic leverage against the U.S. and its allies. The rogue nations have multiple acquisition paths that can provide them with highly-capable LACMs such as direct purchase of advanced LACMs from various countries, to include France, Russia, and China; indigenous development, with or without outside assistance; and development of a highly-capable LACM via the relatively low

cost and technically straightforward conversion of an ASCM such as the Chinese HY-4 Sadsack. Given all these proliferation conditions, which clearly favor the rogue states and not the U.S. and its allies, the probability is quite high that by the 2005 timeframe one or more of the rogue nations will possess a 500- to 1,000-km range biocruise weapon system capable of delivering BW agent payloads in a highly-effective manner against U.S. and allied military operations in regional conflicts around the world and also against military and civilian targets within the U.S. and allied countries.

Just as disturbing, these rogue nation capabilities will likely emerge with little if any warning. The National Intelligence Council's 1999 *Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015* report states:

> A concept similar to a sea-based ballistic missile launch system would be to launch cruise missiles from forward-based platforms. This method would enable a country to use cruise missiles acquired for regional purposes to attack targets in the United States. . . . We also judge that we may not be able to provide much, if any, warning of a forward-based ballistic missile or land-attack cruise missile (LACM) threat to the United States. Moreover, LACM development can draw upon dual-use technologies.[123]

Not only are the rogue nation developments of strategically-significant LACMs difficult for the intelligence community to assess and predict, Director of the CIA, George Tenet, recently testified before the Senate Select Committee on Intelligence that the U.S. intelligence services may be incapable of monitoring the proliferation of nuclear, chemical, and biological expertise and technologies. Tenet also stated that now, more than ever, "we risk substantial surprise."[124] Add to these sobering assessments the disturbing knowledge that some of the rogue states have clearly demonstrated that they will use WMD against an adversary, and that the U.S. and its allies are not likely to deter such use, one can understand the seriousness of the emerging biocruise threat and the concerted U.S. and allied efforts that must be applied in the near term to adequately address this threat.

Notes

1. Jonathan B. Tucker, "The Future of Biological Warfare," in *The Proliferation of Advanced Weaponry: Technology, Motivations, and Responses*, ed. W. Thomas Wander and Eric H. Arnett (Washington, D.C.: American Association for the Advancement of Science, 1992), 73.

2. Humphry Crum Ewing et al., *Cruise Missiles: Precision & Countermeasures*, Bailrigg Memorandum 10 (Lancaster, United Kingdom: Centre for Defence and International Security Studies, 1995), 60.

3. Department of Defense, *Final Report to Congress on the Conduct of the Persian Gulf Conflict*, *Vol I* (Washington, D.C.: U.S. Government Printing Office, April 1992), 244.

4. These examples of United States use of LACMs were obtained from numerous on-line news sources.

5. Susanne M. Schafer, "12/17 Cruise Missiles Reduce Iraqi Military Sites to Rubble," *Nando Times News*, 18 December 1998, n.p.; on-line, Internet, 8 February 2000, available from http://www.business-server.com/newsroom/ntn/world/ 121898/ worldt_ 26518_ S8_body.html.

6. Kori Schake, "Rogue States and Proliferation: How Serious is the Threat?" in *Strategic Assessment 1999: Priorities for a Turbulent World*, ed. Hans Binnendijk et al. (Washington, D.C.: U.S. Government Printing Office, June 1999), 220. The U.S.-identified rogue nations of BW proliferation concern and believed to be sponsors of terrorism are Iran, Iraq, Libya, North Korea, and Syria. There is no single, universally accepted definition of a rogue nation. Rogue states have been defined by the Clinton administration as "recalcitrant and outlaw states that not only choose to remain outside the family [of democracies] but also assault its basic values." Some of the characteristics of rogue nations are that they are aggressively pursuing unconventional means to threaten U.S. and international interests, they do not conform to the norms of international behavior and are not easily persuaded to do so, and they tend to be sponsors of terrorism.

7. Ramesh Thakur, "Arms Control, Disarmament and Non-Proliferation: A Political Perspective," in *Arms Control in the Asia-Pacific Region*, ed. Jeffrey A. Larsen and Thomas D. Miller (Washington, D.C.: U.S. Government Printing Office, August 1999), 43.

8. "Iran, Other Rogue Regimes Developing Cruise Missiles," May 1999, n.p.; on-line, Internet, 1 February 2000, available from http://www.ourjerusalem.com/ documents/febmay99/ 0412docs.htm.

9. National Intelligence Council, *Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015*, September 1999, n.p.; on-line,

Internet, 21 January 2000, available from http://www.usconsulate.org.hk/uscn/others/1999/0909.htm.

10. Richard K. Betts, "The New Threat of Mass Destruction," *Foreign Affairs* 77, no. 1 (January/February 1998): 27.

11. *Ibid*, 28. See also Eugene Gholz, Daryl G. Press, and Harvey M. Sapolsky, "Come Home America: The Strategy of Restraint in the Face of Temptation," *International Security* 21, no. 4 (Spring 1997): 7.

12. Betts, 28.

13. *Ibid*, 28-29.

14. Robin Ranger and David Wiencek, *The Devil's Brews II: Weapons of Mass Destruction and International Security*, Bailrigg Memorandum 17 (Lancaster, United Kingdom: Centre for Defence and International Security Studies, 1997), 16.

15. David G. Wiencek, *Dangerous Arsenals: Missile Threats In and From Asia*, Bailrigg Memorandum 22 (Lancaster, United Kingdom: Centre for Defence and International Security Studies, 1997), 8.

16. Ranger and Wiencek, 17. See also Stephen I. Schwartz, *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940*, Brookings Institution, 1998, n.p.; on-line, Internet, 11 May 2000, available from http://www.brook.edu/FP/PROJECTS/NUCWCOST. After four years of intensive research investigating what the U.S. spent on nuclear weapons, Schwartz concludes that the U.S. spent at least 29 percent of its national defense budget on nuclear weapons. This larger percentage, however, includes not only the costs for the nuclear warheads and strategic delivery systems but also the costs associated with targeting, controlling nuclear weapons, defending against the Soviet Union's nuclear arsenal, dismantling nuclear weapons, nuclear waste management and environmental remediation, and so on.

17. Efraim Karsh, "Rational Ruthlessness: Non-Conventional and Missile Warfare in the Iran-Iraq War," in *Non-Conventional-Weapons Proliferation in the Middle East*, ed. Efraim Karsh, Martin S. Navias, and Philip Sabin (New York: Oxford University Press, 1993), 36-42.

18. Leonard S. Spector, "Nuclear Proliferation in the Middle East: The Next Chapter Begins," in *Non-Conventional-Weapons Proliferation in the Middle East*, ed. Efraim Karsh, Martin S. Navias, and Philip Sabin (New York: Oxford University Press, 1993), 143.

19. Ranger and Wiencek, 9 and 18.

20. Betts, 31.

21. Dennis M. Gormley and K. Scott McMahon, "Counterforce: The Neglected Pillar of Theater Missile Defense," n.p.; on-line, Internet, 29 September 1999, available from http://www.cdiss.org/colsep1.htm.

22. Committee on Armed Services, House of Representatives, *Countering the Chemical and Biological Weapons Threat in the Post-Soviet World* Special Inquiry into the Chemical and Biological Threat, Report to the Congress (Washington, D.C.: U.S. Government Printing Office, 23 February 1993), 4.

23. Willis Stanley and Keith Payne, "Chapter II. Missile Proliferation: Threat and U.S. Response," *Comparative Strategy* 16, no. 2 (1997): 135.

24. Dennis Gormley and Richard Speier, "Cruise Missile Proliferation: Threat, Policy, and Defenses," presentation to the Carnegie Endowment for International Peace Proliferation Roundtable, 9 October 1998, n.p.; on-line, Internet, 21 September 1999, available from http://www.ceip.org/programs/npp/cruise4.htm.

25. Betts, 32.

26. Edward M. Eitzen, "Use of Biological Weapons," in *Medical Aspects of Chemical and Biological Warfare*, eds. Frederick R. Sidell, Ernest T. Takafuj, and David R. Franz (Washington, D.C.: Office of The Surgeon General at TMM Publications, 1997), 446.

27. U.S. Congress, Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559 (Washington, D.C.: U.S. Government Printing Office, August 1993), 54.

28. World Health Organization Group of Consultants, *Health Aspects of Chemical and Biological Weapons* (Geneva, Switzerland: World Health Organization, 1970), 98-99.

29. Lester C. Caudle, "The Biological Warfare Threat," in *Medical Aspects of Chemical and Biological Warfare*, eds. Frederick R. Sidell, Ernest T. Takafuj, and David R. Franz (Washington, D.C.: Office of The Surgeon General at TMM Publications, 1997), 437-450.

30. Biological agents are either replicating agents, bacteria or viruses, or nonreplicating materials, toxins or physiologically active proteins or peptides, that can be produced by living organisms. The replicating nature and extreme infectivity at low doses of pathogens such as *Bacillus anthracis* (organism that causes anthrax) and *Yersinia pestis* (organism that causes plague) are what make them weight-for-weight more deadly than CW nerve agents. Additionally, toxins such as the staphylococcal enterotoxins and botulinum toxins are extraordinarily toxic--1,000- to 10,000-fold more toxic than classic nerve agents. For further information, see *The Biological & Chemical Warfare Threat* (Washington, D.C.: U.S. Government Printing Office, 1999), 1-23; Frederick R. Sidell and David R. Franz, "Overview: Defense Against the Effects of Chemical and Biological

Warfare Agents," in *Medical Aspects of Chemical and Biological Warfare*, eds. Frederick R. Sidell, Ernest T. Takafuj, and David R. Franz (Washington, D.C.: Office of The Surgeon General at TMM Publications, 1997), 1-7; and Eitzen, 437-450.

31. Caudle, 458. See also Lord Lyell, "Chemical and Biological Weapons: The Poor Man's Bomb," 4 October 1996, n.p.; on-line, Internet, 11 May 2000, available from http://www.pgs.ca/pages/cw/cw980327.htm. The author of this article states that "a more specific assessment suggests that the development of biological weapons would cost less than $100,000, require five biologists, and take just a few weeks using equipment that is readily available."

32. *The Biological & Chemical Warfare Threat*, 1.

33. Jonathan B. Tucker, "The Future of Biological Warfare," in *The Proliferation of Advanced Weaponry: Technology, Motivations, and Responses*, ed. W. Thomas Wander and Eric H. Arnett (Washington, D.C.: American Association for the Advancement of Science, 1992), 67.

34. W. Seth Carus, *Bioterrorism and Biocrimes: The Illicit Use of Biological Agents in the 20th Century* (Washington, D.C.: Center for Counterproliferation Research, National Defense University, August 1998 [March 1999 revision]), 25.

35. Carus, 24.

36. Tucker, 67.

37. Carus, 25.

38. *Ibid*, 26.

39. Milton Leitenberg, "Deadly Unknowns about Iraq's Biological Weapons Program," 9 February 2000, n.p; on-line, Internet, 14 February 2000, available from http://www.isis-online.org/publications/iraq/leitenberg.html.

40. Center for Nonproliferation Studies, Monterey Institute of International Studies, "Chemical and Biological Weapons Possession and Programs: Past and Present," n.p.; on-line, Internet, 14 February 2000, available from http://www.cns.miis.edu/research/cbw/possess.htm.

41. Arnold Beichman, "Arsenal of Germs in Iran?" *The Washington Times*, 26 January 1999.

42. Paula DeSutter, "Deterring Iranian NBC Use," *National Defense University Strategic Forum*, no. 110 (April 1997): 1.

43. Beichman.

44. Tony Capaccio, "CIA: Iran Holding Limited Stocks of Biological Weapons," *Defense Week* 17, no. 32 (5 August 1996), 15.

45. Barbara Crossette, “Iraq Suspected of Secret Germ War Effort,” *The New York Times On the Web*, 8 February 2000, n.p.; on-line, Internet, 10 February 2000, available from http://www10.nytimes.com/library/world/mideast/020800iraq-inspect.html.

46. Milton Leitenberg, “Prescription for Disaster,” *Washington Post*, 10 February 2000, A23; on-line, Internet, 14 February 2000, available from http://www.washingtonpost.com/wp-srv/WPlate/2000-02/10/1151-021000-idx.html. See also Leitenberg, “Deadly Unknowns about Iraq's Biological Weapons Program.”

47. Edward M. Eitzen and Ernest T. Takafuji, “Historical Overview of Biological Warfare,” in *Medical Aspects of Chemical and Biological Warfare*, eds. Frederick R. Sidell, Ernest T. Takafuj, and David R. Franz (Washington, D.C.: Office of The Surgeon General at TMM Publications, 1997), 421-422.

48. Leitenberg, “Deadly Unknowns about Iraq's Biological Weapons Program.”

49. Center for Nonproliferation Studies, Monterey Institute of International Studies, “Weapons of Mass Destruction Capabilities and Programs: Iraq,” n.p.; on-line, Internet, 8 February 2000, available from http://www.cns.miis.edu/research/wmdme/iraq.htm. See also Michael Eisenstadt, “Missiles and Weapons of Mass Destruction (WMDs) in Iraq and Iran: Current Developments and Potential for Future Surprises,” 23 March 1998, n.p.; on-line, Internet, 9 September 1999, available from http://www.washingtoninstitute.org/ media/ballistic.htm.

50. Arms Control and Disarmament Agency, *Adherence to and Compliance with Arms Control Agreements: 1997 Annual Report to Congress*, n.p.; on-line, Internet, 14 February 2000, available from http://dosfan.lib.uic.edu/acda/reports/annual/chpt7.htm.

51. Center for Nonproliferation Studies, Monterey Institute of International Studies, “Chemical and Biological Weapons Possession and Programs: Past and Present.”

52. Carus, 32.

53. Center for Nonproliferation Studies, Monterey Institute of International Studies, “Chemical and Biological Weapons Possession and Programs: Past and Present.”

54. “Japan Concerned Over N. Korea Biochemical Warheads,” 14 September 1999, n.p.; on-line, Internet, 12 January 2000, available from http://tmd.ggwdp.net/tmd25.htm#Japan Concerned Over N. Korea Biochemical Warheads.

55. The Ministry of National Defense, Republic of Korea, *Defense White Paper 1998* (Korea Institute for Defense Analysis, 1999), 65.

56. Michael Eisenstadt, “Syria's Strategic Weapons,” *Jane's Intelligence Review* 5, no. 4 (April 1993): 168-169.

57. *A Study On Exploring U.S. Missile Defense Requirements in 2010: What Are the Policy and Technology Challenges?*, April 1997, n.p.; on-line, Internet, 6 October 1999, available from http://fas.org/spp/starwars/ advocate/ifpa/report696_ch4_syr.htm.

See also Center for Nonproliferation Studies, Monterey Institute of International Studies, "Chemical and Biological Weapons Possession and Programs: Past and Present" and Eisenstadt, 169.

58. *A Study On Exploring U.S. Missile Defense Requirements in 2010: What Are the Policy and Technology Challenges?*

59. U.S. Congress, Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559 (Washington, D.C.: U.S. Government Printing Office, August 1993), 3.

60. In Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 23 March 1994 (amended through 15 April 1998), a cruise missile is defined as a "guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity; depends on the dynamic reaction of air for lift and upon propulsion forces to balance drag." A guided missile is "an unmanned vehicle moving above the surface of the Earth whose trajectory or flight path is capable of being altered by an external or internal mechanism."

61. The range of cruise missiles is stated throughout the literature in a variety of units: kilometers (km), miles (mi) and nautical miles (nmi). The conversion between these units is 1 km = 0.621 mi = 0.54 nmi.

62. National Air Intelligence Center, *Ballistic and Cruise Missile Threat*, NAIC-1031-0985-99 (Dayton, OH: Wright-Patterson Air Force Base, April 1999), 6.

63. Centre for Defence and International Security Studies, "Cruise Missile Capabilities: An Assessment," n.p.; on-line, Internet, 1 February 2000, available from http://www.cdiss.com/ tabanaly.htm.

64. W. Seth Carus, *Cruise Missile Proliferation in the 1990s*, (Washington, D.C.: Center for Strategic and International Studies), 15.

65. *Ibid*.

66. Marshall Brain, "How Cruise Missiles Work," n.p.; on-line, Internet, 21 September 1999, available from http://www.howstuffworks.com/cruise.htm.

67. Humphry Crum Ewing et al., *Cruise Missiles: Precision & Countermeasure*, Bailrigg Memorandum 10 (Lancaster, United Kingdom: Centre for Defence and International Security Studies, 1995), 49 and 51. Inertial Navigation systems (INS) use gyroscopes and accelerometers to detect changes in speed and direction of the LACM which can then be used to compute changes in relative positions. Although an INS guidance system has the advantage of being jam-proof, the gyroscopes have inherent inaccuracies which result in increasing positional errors (called drift) with increasing LACM flight time. As an example, the U.S. TLAM INS drifts by 900 meters per hour. At the TLAM's cruising speed of 800 km per hour, an uncorrected INS would result in a 1.8 km positional error for striking a target at a range of 1,600 km. Thus, to strike targets

at long range, the LACM's INS must be supplemented with other guidance systems such as GPS or TERCOM. TERCOM corrects any INS by taking periodic fixes on the terrain features (must be areas of distinctive topography) over which the LACM is flying. To accomplish this, the TERCOM system uses an on-board computer, in which maps of the relevant terrain, obtained from high-resolution satellite images, are stored, along with a radar altimeter. The computer correlates data received from altimeter readings with elevation data from the stored maps. The system then calculates the corrections needed to put the LACM back on course and provides this information to the missile's autopilot.

68. DSMAC is a two-dimensional, map-matching technique that employs an onboard sensor to obtain a sequence of images of the ground directly below the missile. The images are compared to reference data stored in the missile's navigational computer, and position changes are made as needed prior to final target acquisition. DSMAC is a complex technology that significantly improves the terminal accuracy of the cruise missile.

69. The MTCR was created in 1987 by the G-7 governments of Canada, France, Italy, Japan, UK, U.S., and West Germany. It is an informal, voluntary export control arrangement with guidelines prohibiting the sale or transfer of certain categories of ballistic and cruise missiles and their related technologies. The Regime grew out of the mutual fears of the G-7 nations that rogue states would acquire offensive missiles for use as WMD delivery platforms. The current membership includes 32 countries.

70. K. Scott McMahon and Dennis M. Gormley, *Controlling the Spread of Land-Attack Cruise Missiles*, The AISC Papers, No. 7 (Marina del Rey, CA: The American Institute for Strategic Cooperation (AISC), January 1995), 22.

71. DGPS is a method of correcting GPS that allows a weapon system to obtain extremely high positional accuracies. The concept of DGPS is as follows. A receiver is placed at a pre-surveyed location whose position has been determined very accurately. Both the GPS receiver at the known location and the DGPS receiver on the weapon system acquire the same set of GPS signals from the same set of satellites. The errors in the GPS signals are determined by comparing the surveyed site's known position to the position determined using the GPS signals. Correction terms are then calculated and transmitted to the weapon system DGPS receiver allowing elimination of most of the errors of the GPS signals. The DGPS technique can yield weapon system positional accuracies of 1 to 5 m.

72. McMahon and Gormley, 21.

73. "IKONOS Satellite Launches into Space," n.p.; on-line, Internet, 1 October 1999, available from http://www.spaceimage.com/newsroom/releases/1999/inorbit.htm. The U.S. firm, Space Imaging, successfully launched its IKONOS satellite on 24 September 1999. This is the first commercial imaging satellite of its kind, simultaneously collecting 1-m resolution panchromatic and 4-m resolution multispectral images. Space Imaging is now selling and distributing imagery. Many other commercial imaging

satellites, both U.S. and foreign, providing 1-m resolution imagery are scheduled for launch in 2000, 2001, 2002 and so on. See also McMahon and Gormley, 24.

74. McMahon and Gormley, 25.

75. Dennis Gormley and Richard Speier, "Cruise Missile Proliferation: Threat, Policy, and Defenses," presentation to the Carnegie Endowment for International Peace Proliferation Roundtable, 9 October 1998, n.p.; on-line, Internet, 21 September 1999, available from http://www.ceip.org/programs/npp/cruise4.htm.

76. Dennis M. Gormley, "Hedging Against the Cruise-Missile Threat," *Survival*, Spring 1998, 92-111; on-line, Internet, 21 September 1999, available from http://www.ceip.org/ programs/npp/gormley%20survival.htm.

77. National Intelligence Council, *Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015*.

78. Ewing, 50.

79. Carus, 22.

80. David A. Fulghum, "Stealth, Cheap Technology Complicate Defense Schemes," *Aviation Week & Space Technology* 147, no. 2 (14 July 1997): 47.

81. *Ibid*.

82. Bryan Bender, "Cruise Control," *Jane's Defence Weekly* 30, no. 3 (22 July 1998): 21.

83. Dennis M. Gormley, "Remarks from a Panel on the Missile Proliferation Threat at the Conference on Nuclear Non-Proliferation: Enhancing the Tools of the Trade," 9-10 June 1997, Washington, D.C., n.p.; on-line, Internet, 29 September 1999, available from http://www.ceip.org/programs/npp/np9715gohtm. See also K. Scott McMahon and Dennis M. Gormley, *Controlling the Spread of Land-Attack Cruise Missiles*, The AISC Papers, No. 7 (Marina del Rey, CA: The American Institute for Strategic Cooperation (AISC), January 1995), 14-18; Amy Truesdell, "Cruise Missiles: The Discriminating Weapon of Choice?," *Jane's Intelligence Review*, February 1997, 87-90; and Carus, 69 and 83.

84. Gormley and Speier.

85. Carus, 25.

86. *Militarily Critical Technologies List (MCTL) Part II: Weapons of Mass Destruction Technologies, Section I - Means of Delivery Technology*, September 1998, II-1-2; on-line, Internet, 10 September 1999, available from http://www.fas.org/irp/threat/ mctl98-2/p2sec01.pdf.

87. K. Scott McMahon and Dennis M. Gormley, *Controlling the Spread of Land-Attack Cruise Missiles*, The AISC Papers, No. 7 (Marina del Rey, CA: The American Institute for Strategic Cooperation (AISC), January 1995), 1.

88. National Air Intelligence Center, *Ballistic and Cruise Missile Threat*, NAIC-1031-0985-99 (Dayton, OH: Wright-Patterson Air Force Base, April 1999), 19.

89. Robert Wall, "Cruise Missile Threat Grows," *Aviation Week & Space Technology* 149, no. 4 (27 July 1998): 24.

90. *Ibid*.

91. The Arms Control Association, "The Missile Technology Control Regime," July 1999, n.p.; on-line, Internet, 21 January 2000, available from http://www.armscontrol.org/FACTS/ mtcr.html. The MTCR was created in April 1987 to restrict the proliferation of missiles and related technology. It is the only multilateral missile nonproliferation Regime and is neither an international agreement nor a treaty. The MTCR is a voluntary arrangement among countries (currently 32) which share a common interest in arresting missile proliferation. The Regime consists of a common export control policy (the Guidelines) applied to a shared list of controlled items (the Annex) which each MTCR member implements in accordance with its national legislation. The purpose of the Regime is to limit the spread of missiles and unmanned air vehicles/delivery systems capable of carrying a 500 kilogram payload at least 300 kilometers. The MTCR Annex of controlled items is divided into two sections (Category I and Category II) and includes military and dual-use equipment and technology relevant to missile development, production and operation.

Category I

According to the MTCR Guidelines, exports of Category I items are subject to a strong presumption of denial and are rarely licensed for export. Category I items include complete missile systems (ballistic missiles, space launch vehicles, and sounding rockets) and unmanned air-vehicle systems (including cruise-missile systems, target drones, and reconnaissance drones) capable of delivering at least a 500-kg payload to a range of at least 300 km, as well as the specially designed production facilities for these systems. Also included are certain complete subsystems such as rocket engines or stages; reentry vehicles; guidance sets; thrust vector controls; and warhead safing, arming, fuzing and firing mechanisms. Transfers of production facilities for Category I items are flatly prohibited.

Category II

The MTCR Guidelines permit licensing of Category II (dual-use) items as long as they are not destined for end-use in the development of a missile of MTCR range/payload capability. Category II items cover a wide range of parts, components and subsystems

such as propellants, structure materials, test equipment and facilities and flight instruments. These items may be exported at the discretion of the MTCR Partner Government, on a case by case basis, for acceptable end uses. They may also be exported under government-to-government assurances which provide that they not be used on a missile system capable of delivering a 500-kg payload to a range of at least 300 km.

92. K. Scott McMahon, "Cruise Missile Proliferation: Threat, Policy, and Defenses," presentation to the American Institute of Engineers Conference on Missile Defense, 5 March 1999.

93. *Ibid*.

94. Dennis M. Gormley, "Hedging Against the Cruise-Missile Threat," *Survival*, Spring 1998, 92-111; on-line, Internet, 21 September 1999, available from http://www.ceip.org/programs/npp/gormley%20survival.htm.

95. Mr. K. Scott McMahon, Assistant Program Manager for Defense Policy, Pacific-Sierra Research Corporation, Arlington, Virginia, telephone conversations and email exchanges with author, 23 September 1999, 1 October 1999 and 8 October 1999.

96. Dennis Gormley and Richard Speier, "Cruise Missile Proliferation: Threat, Policy, and Defenses," presentation to the Carnegie Endowment for International Peace Proliferation Roundtable, 9 October 1998, n.p.; on-line, Internet, 21 September 1999, available from http://www.ceip.org/programs/npp/cruise4.htm. See also Jean-Paul Philippe, "Matra to Develop APTGD Missile: A New 'Stealth' Cruise missile for France," *Military Technology* 19, no. 2 (February 1995): 60-62.

97. Gormley.

98. *Ibid*.

99. Richard D. Fisher, Appendix to "How America's Friends Are Building China's Military Power," *The Heritage Foundation Backgrounder*, no. 1146, 5 November 1997, n.p.; on-line, Internet, 2 February 2000, available from http://www.heritage.org/library/categories/natsec/bg1146/appendix.html.

100. *Ibid*.

101. Richard D. Fisher, Jr., "China Increases Its Missile Forces While Opposing U.S. Missile Defense," *The Heritage Foundation Backgrounder*, no. 1268, 7 April 1999, n.p.; on-line, Internet, 12 January 2000, available from http://www.heritage.org/library/backgrounder/bg1268es.html.

102. "Current Missile News," n.p., on-line, Internet, 10 September 1999, available from http://www.cdiss.com/99aug19_b.htm.

103. Seymour Johnson, "China Seeks Technology for Next-Generation Missiles," *Foreign Affairs News*, 3 October 1999, n.p.; on-line, Internet, 3 October 1999, available

from http://208.138.42.193/forum/a37f7495d3eac.htm. See also Richard D. Fisher, Appendix to "How America's Friends Are Building China's Military Power."

104. Richard D. Fisher, Jr., "China Increases Its Missile Forces While Opposing U.S. Missile Defense."

105. David A. Fulghum, "Cruise Missile Threat Spurs Pentagon Research," *Aviation Week & Space Technology* 147, no. 2 (14 July 1997): 44.

106. Humphry Crum Ewing et al., *Cruise Missiles: Precision & Countermeasures*, Bailrigg Memorandum 10 (Lancaster, United Kingdom: Centre for Defence and International Security Studies, 1995), 37.

107. Amy Truesdell, "Cruise Missiles: The Discriminating Weapon of Choice?," *Jane's Intelligence Review*, February 1997, 89.

108. *Ibid*, 90.

109. *Ibid*.

110. Donald Rumsfeld, et al., "The Growing Ballistic Missile Threat: How Much, How Soon, and How Dangerous?" *The Heritage Foundation Heritage Lectures*, no. 632, 1 February 1999, n.p.; on-line, Internet, 2 February 2000, available from http://www.heritage.org/library/ lecture/h1632.html.

111. *Ibid*.

112. *A Study On Exploring U.S. Missile Defense Requirements in 2010: What Are the Policy and Technology Challenges?*, April 1997, n.p.; on-line, Internet, 6 October 1999, available from http://fas.org/spp/starwars/ advocate/ifpa/report696_ch4_iran.htm.

113. *Ibid* and McMahon, telephone conversations.

114. *A Study On Exploring U.S. Missile Defense Requirements in 2010: What Are the Policy and Technology Challenges?*

115. Ewing, 35 and 40.

116. McMahon, telephone conversations.

117. Ewing, 40.

118. Michael Eisenstadt, "Syria's Strategic Weapons," *Jane's Intelligence Review* 5, no. 4 (April 1993): 172.

119. Gormley and Speier.

120. McMahon, telephone conversations.

121. *Ibid*.

122. Robert Wall, "Smarter TBMs on Horizon," *Aviation Week & Space Technology*, 30 August 1999, 31.

123. National Intelligence Council, *Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015*.

124. Judith Miller, "U.S. Intelligence: Flying Blind in a Dangerous World," *New York Times*, 6 February 2000, n.p.; on-line, Internet, 7 February 2000.

USAF Counterproliferation Center

The USAF Counterproliferation Center was established in 1999 to provide education and research to the present and future leaders of the USAF, to assist them in their activities to counter the threats posed by adversaries equipped with weapons of mass destruction.

Barry R. Schneider, Director
USAF Counterprofliferation Center
325 Chennault Circle
Maxwell AFB AL 36112-6427

Email: Barry.Schneider@maxwell.af.mil

Jo Ann Eddy, Associate Editor
The Counterproliferation Papers

Email: JoAnn.Eddy@maxwell.af.mil

(334) 953-7538 (DSN 493-7538)